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RARE AND ENDANGERED FERNS OF THE WESTERN GHATS OF SOUTH INDIA

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ABSTRACT
A general account of the ferns of the Western Ghats is given and reference made to R.H.Beddome's records from South India. The major hill-stations in Tamil Nadu and Kerala south of Palghat Gap and the Nilgiris in Tamil Nadu and their forests are mentioned. The occurrence of 46 rare and endangered species is described and notes given on their conservation and ecology.

INTRODUCTION
The Western Ghats lie between 8° 22′ and 20° 40′ North at about 73° 77′ East and cover a distance of 1600 km from the Tapiti valley in Gujarat State south to Kanyakumari in Tamil Nadu state. This series of mountain ranges including the Nilgiri Hills, Anamallays Hills and Palni Hills, run north-south along the West coast traversing the states of Gujarat, Maharashtra, Goa, Karnataka, Kerala and Tamil Nadu. The otherwise more or less continuous hill ranges have a major discontinuity at the Palghat Gap, separating the ranges of the Nilgiri Hills from the Anamallays. The Ghats descend steeply in the west, facing the Arabian sea, whereas they merge gradually through a series of hills with the Deccan plateau in the East. Anamudi, rising to 2695 m is the highest peak south of the Himalaya. The Western Ghats receive heavy rainfall both from the south-west and north-east monsoons. The annual rainfall varies from 1000-5000 mm depending on altitude. Various types of forest such as scrub-forest (200-500 m), moist deciduous forest (500-900 m) and tropical moist evergreen forest (1200-1500 m) occur on the hills. A characteristic feature of the Western Ghats is the occurrence of *sholas* (high altitude forest with a distinct abrupt boundary and trees with short trunks) above 1500 m. They are found in patches in hollows and sheltered folds surrounded by rolling downs in the Anamallays, Nilgiris and Palni hills and in the high ranges of Kerala and Karnataka. The high plateaus above of 1700-1900 m are covered with savannah with scattered shrubs. A remarkable floristic diversity is evident from the fact that of about 15,000 species of flowering plants estimated to occur in India, about 4,000 are found in the Western Ghats. There are 57 endemic genera in the Western Ghats alone and 84 in the rest of India (Nair & Daniel 1986).

BEDDOME'S RECORD OF FERNS IN THE WESTERN GHATS
The earliest noteworthy work on the ferns of South India by Gustav Kunze (1851), who recorded and described ferns from the Nilgiris Hills, was followed by the work of Colonel Richard Henry Beddome (1864), Chief Conservator of forests for the entire Madras region, who recorded 240 species from South India and 61 from Ceylon. Of the 240 south Indian species, 184 were from Tamil Nadu, 38 from Kerala, 6 from Karnataka and one from Andhra Pradesh. Beddome also mentioned " Western side" 11 times with no mention of particular locality. In his *Ferns of Southern India* (1864), Beddome mentioned the Anamallays 83 times, Nilgiris 75 times, Palnis 15 times and Coimbatore Hills 11 times. It appears strange that Beddome who recorded so many ferns from Anamallays and Nilgiris, did not refer to the Tirunelveli Hills from where the present author has collected about 160 species, of which some are extremely rare in South India.

The nomenclature used by Beddome was mostly based on that of the early British botanists,

notably Moore and Hooker, and particularly Baker in Hooker and Baker (1868) who generally had broader species-concepts than today. According to the late Prof. R.E. Holttum (pers.comm.), Beddome misapplied names for Indian ferns in quite a number of cases. However Beddome's works remain the most comprehensive important reference materials for understanding Indian ferns today. The most important modern revision of much of Beddome's work has been that of Sledge (1956-1982) in various papers concerning Sri Lankan ferns, including a comprehensive survey (Sledge 1982).

Although the author has been able to find nearly all of the species mentioned by Beddome he has not seen the following six species which Beddome had recorded from the Western Ghats: *Osmunda collina* Sledge, *Lygodium circinnatum* (Burm. f.) Sw., *L. japonicum* (Thunb.) Sw., *Trichomanes bimarginatum* v.d.Bosch, *Pronephrium thwaitesii* (Hook.) Holltum, *Anogramma leptophylla* (L.) Link. Most of these species presumably escaped my notice, though it is also possible that some could have been eliminated by the continuous destruction of primary forests in the area. Beddome's specimen of *O. collina*, however, may well not have originated in India, but in Sri Lanka (see Sledge 1981:10-11).

THE AUTHOR'S FIELD WORK ON THE WESTERN GHATS

The author first carried out field work in the Palni Hills (from 1969-1975) based on Kodaikanal, collecting 2,500 numbers consisting of 137 species and 13 so-called varieties (Manickam, 1986). The field work was intensive and extensive, covering practically all the forests on the high plateau and on the northern, eastern and southern slopes. At that time there were not many bus routes, and being without a personal vehicle, long distances were covered on foot on bridle-paths from the high summits to the foothills, to collect ferns. On the high plateau the main *sholas* explored were those around Berijam Lake, Kukal, Vembadi peak and the township reservoir. There are dense *sholas* on the south western-border of the states of Tamil Nadu and Kerala at around 2100 m, particularly on the Tamil Nadu side where the author undertook several trips.

Following this period major field work on the Western Ghats was continued from 1984-87 when the ecology of ferns was particularly studied, inspired by the work of Professor Jan Kornas. The area studied covered some 18,000 sq.kms south of the Palghat gap over a length of 450 kms in both Tamil Nadu and Kerala. Altogether 134 days were spent in the field, covering the area extensively on foot and realizing a total of 4058 collections. Very few primary forests remain south of Palghat gap in the state of Kerala because of extensive cultivation of economically useful crops. In the Western Ghats above 1500 m, there are 750 km^2 of tea-cultivation, 1500 km^2 of coffee and 825 km^2 of cardamon . The only primary forests in Kerala which the author could explore are the undisturbed riparian forests west of Anamudi peak, a few sholas north of Munnar, the forests within the Kerala border in Agasthiamalai and the forests west of the Anamallays where a motor road runs from Valparai town in Tamil Nadu to Chalakudi in Kerala. Mention should be made of Mackay's path (36km) between Akkamalai in Tamil Nadu and Munnar in Kerala. While trekking along this path, many large evergreen forests were encountered and one very rare species, *Vittaria flexuosa* Fée, was also collected. The forests on the way to Sabarimala are also intact from where the rare species *Athyrium cumingianum* (C. Presl) Ching. was collected. No forests were seen along the routes Munnar-Palai, Palai-Thekkadi and Thekkadi-Allepy. There are still some forests in the Ponmudi hills near Trivandrum on the western slopes and a few undisturbed *sholas* on the top.

The author has visitied vast stretches of primary forests in the Western Ghats of Tamil Nadu. Even though the entire high plateau of the Anamallays, from Akkamalai on the east to Sholayar Dam on the West, has been entirely converted for tea-plantation, there are still vast dense forests east of Akkamalai (1800 m), both on the high plateau and on the slopes. Some rare species such as *Leptochilus thwaitesianus* Fée, *Elaphoglossum nilgiricum* Kragina ex Sledge, *Asplenium*

ensiforme Wall. ex Hook. & Grev. and a few other, previously unreported species, were collected from these forests. Beddome did not explore the Tirunelveli Hills, but the author has collected about 160 species there, of which some are extremely rare in South India. The Tirunelveli Hill ranges consist of the Agasthiamalai Range (1800 m), Kothayar Range (1500 m) and Kalakad Range (1100 m) which are all close to each other. The Kalakad Range is a virgin area with only a few acres of cardamon cultivation, the Agasthiamalai Range remains totally undisturbed while there are a few hundred acres of tea cultivation in the Kothayar Range. In all three there are dense moist forests where numerous fern-species occur luxuriantly. There are also evergreen forests south of the Tirunelveli ranges and close to the of town Nagercoil around the villages of Balamore (900 m), Maramalai (700 m) and Korimoni (900 m). Beddome made a few records of ferns from the well-known tourist-spot, Courtallam, famous for its five-pronged water-fall.

After a satisfactory survey of the southern parts of the Western Ghats, thorough exploration was undertaken of the Nilgiris, north of Palghat gap. Field-work began in October 1991 and ended in March 1992, totalling 65 field-days during which a total of 2200 field- numbers were collected. The total area of the Nilgiris is 2549 km^2, of which 1000 km^2 is under cultivation of tea and other economically useful crop plants. Dodabetta (2638 m) on the eastern summit of the Nilgiris is the highest point. Nearly all the major forests and most of the small pockets of sholas were explored in the 216 reserve-forests throughout the Nilgiris. Only Lamb's Rock Shola, a reserve-forest near Conoor, is close to areas of major habitation. There are a dozen sholas along the road running from Ootcamund to Naduvattom (42 km). From this road two other roads diverge, one leading to Governor Shola and the other to Terrace Estate. All the *sholas* along these roads were explored, collecting some very rare species. On the high plateau there is a 203 km long circular road, passing through numerous villages and several sholas where fern-collection was also carried out. Even though all the major sholas on the Kundha, Kottagiri and Coonoor ranges were thoroughly explored, the fern diversity was not very high. The northern slopes of the Nilgiris, where Muthumalai sanctuary is situated, are rather dry with no dense forests. The high plateau is the wettest part of the Nilgiris and there are numerous fern-species there. Out of 140 species collected from the Nilgiris, 75 were found in the sholas on the high plateau.

Fifty five species of ferns were collected from the northern slopes of the moist Gudalur range (1300 m). From the Nadugani area which is close to Kerala rare species such as *Pronephrium articulatum* (Houlst. & Moore) Holttum, *Pteris mertensioides* Willd. and *Pteris longipes* D.Don were collected. Collections were made on the eastern slopes from the top down to the foothills along four different routes - via Kottagiri, via Coonoor,via Manjoor and via Droog. Though the author's fern-collection in the Nilgiris has been thorough, only one species, *Loxogramme parallela* Copel., was found which was not collected from the Western Ghats south of Palghat gap. Certain species rare in the south of India such as *Asplenium erectum Bory ex Wild.* Swartz, *Belvisia revoluta* (Bl.) Copel., *Diplazium dilatatum* Bl., *Histiopteris incisa* (Thunb.) J. Smith, *Humata repens* (L.f.) Diels and *Pronephrium thwaitesii* (Hook.) Holttum, all of which Beddome had recorded from the Nilgiris, were not collected again by the present author. A comparison of the fern floras of the Nilgiris with that of the Palnis, which are similar in altitude, area and climate would be of interest and will be dealt with in a separate paper.

CONSERVATION

Most fern species, being shade and moisture loving, grow in the interior of sholas and forests. Any disturbance of the vegetation, even though not directly to the ferns themselves, will affect the microclimate and lead to the destruction of ferns. When trees are felled, the epiphytes are automatically destroyed with them. A number of epiphytic and lithophytic ferns on the Palni

Hills, which the author observed 22 years ago, are to be found no more in the same locations, or perhaps even destroyed altogether, due to the removal of forest-cover. Ferns growing on semi-exposed sites disappear when full sunlight is allowed in by cutting trees at the periphery of forests. In certain riparian forests in the Palnis *Diplazium brachylobum* has been completely eradicated due to the removal of trees to make way for banana-cultivation. Today most of the sholas on the high plateau of the Palnis have been cleared for planting monoculture forests of *Pinus*, *Acacia*, *Eucalyptus* etc. On the south-western slopes which are the wettest parts of the Palnis, large areas of forests have been destroyed for cardamon cultivation which is particularly destructive as, unlike for many other crops, planting occurs even right into the stream-gulleys where it thrives and destroys these special refuges of ferns. Very rare species such as *Diplazium cognatum* (Hieron.) Sledge, *Microlepia majuscula* (Lowe) T. Moore and *Lastreopsis tenera* (R.Br.) Tindale were not found anymore in these areas during the author's recent field- trips. The cultivation of coffee, bananas and oranges on the north-eastern slopes has also led to the elimination of moist deciduous forests there. *Diplazium cognatum*, a species restricted to Sri Lanka and South India, and abundant on these slopes 15 years ago, was not found here recently by the present author.

There are a number of developments that lead to the destruction of forests and, indirectly, of the fern-flora. Trees are felled for wood-supplies to industry, for constructing multi-purpose river-valley projects, for road-construction, for rehousing refugees etc. There are hundreds of dams in the Western Ghats and 631 dams in Maharashtra alone. Ferns preferring semi-aquatic habitats disappear when dams are constructed. The government spends millions of rupees in its programmes ostensibly aimed at conserving forest-cover and yet, ironically, also allows big agencies to fell-forest trees for industry. We have to discover balanced ways of preserving the integrity of natural resources and of conserving certain key localities properly while working for human-development and progress.

Many pteridophytes are very sensitive to microclimate changes and hence are of considerable importance for understanding subtle changes in the environment. In evergreen forests at medium (1500 m) and high altitudes (2000 m) in the Western Ghats ferns are the dominant constituent of the ground-flora and hence any disturbance inflicted on them is sure to affect the biological equilibrium in forest-ecosystems. In the Palni and Nilgiri Hills, where human interference is enormous, forests are protected by fencing, and forest officers periodically visit the forests in an attempt to prevent human interference. Apart from conserving ferns *in situ*, certain very threatened species should also be preserved *ex situ* by cultivating and propagating plants in gardens and green-houses at different altitudinal levels with a view to re-establishing them in the wild. It is also important that field botanists avoid ruthlessly collecting rare species and make sure that they leave the bulk of plants to continue to grow and reproduce in the wild.

RARE AND ENDANGERED SPECIES

In the following list all the records given were collected by the author unless otherwise stated as the collections represented in major herbaria have not so far been examined and included in the survey.

1. *Adiantum poiretii* Wikstr. L.

Collected first under tea-plants at Munnar at 1800 m and later from the Naduvattom-Gudalur road in the Nilgiris at 1700 m. It occurs in the sheltered parts of road- cuttings under trees.

Distribution: India (Tamil Nadu and Kerala), Sri Lanka, Central and South America, Africa, East African Islands. As stated by Sledge (1973: 154), this is the species reported by Beddome as *A. aethiopicum*, the S. Indian sheets so- named at Kew being *A. poiretii*.

2. *Athyrium cumingianum* (C. Presl) Ching.

Three findings in Kerala and Tamil Nadu have been made. It was seen on the roadside at Pamba (Kerala) at 900 m, on the roadside at Sabarimala in (Kerala) and in the Mnamboli range in the Anamallays in Tamil Nadu at 800 m. In all cases it occurs on fully shaded earth- banks. The serrate margin and the dark green colour of the simple pinnae are characteristic.

Distribution: India (Assam, South India), Sri Lanka, S. China, S.E. Asia and Japan.

3. *Asplenium nidus* L.

This is a beautiful epiphytic fern with glossy simple leaves forming a large basket found in evergreen forests at 600-800 m. It was collected from a shola near Sabarimala, Anakundhi shola at Top Slip in the Anamallays and at Ellamai valley and Manamboli forest in the Nilgiris.

Distribution: N.E. and S. India, China, Japan, S.E. Asia.

4. *Asplenium ensiforme* Wall. ex Hook.& Grev.

The only record made by the author is from the shola on the way from Akkamalai to Grass-hill in the Anamallays at 1800 m. where it was found forming a dense tuft hanging from tree trunks.

Distribution: Himalaya and S. India, Nepal, Bhutan, Burma, Sri Lanka, S. China, Thailand, Vietnam.

5. *Asplenium crinicaule* Hance

A small epiphytic species collected in 1970 from tree trunks at Manalur coffee estate in the Palnis at l000 m, but now disappeared from this area. Later collected from Kadambarai forest in the Anamallays.

Distribution: South India, E. Himalaya, China.

6. *Asplenium polydon* G.Forster

Collected in 1970 from Palamalai slopes in the Palnis, in 1984 from Kannikatty in the Tirunelveli Hills and in 1992 from Mnamboli forest in the Anamallays. This species is a low altitude (700 m), terrestrial or epiphytic fern, only reported by Beddome as *A. falcatum* Lam. (See Morton 1967 and Sledge 1982).

Distribution: South India, Sikkim, Sri Lanka, Bangladesh, Malay Peninsula, Indonesia, Australia, New Zealand, Africa, Polynesia, S. China, the Philippines.

7. *Botrychium daucifolium* Wall. ex Hook & Grev.

Collected from three different forests in the Palnis (1800 m), from the Kalakad Hills (1100 m) and from the sholas in the Coonoor and Kundha Ranges in the Nilgiris (1800 m). This species, which had formed a large colony at the locality in the Kalakad hills, has now disappeared from that site.

Distribution: N.E. India, Myanaung (Burma), S. China, Sri Lanka, Malay Archipelago, Indonesia, the Philippines, Fiji.

8. *Botrychium lanuginosum* Wall. ex Hook.& Grev.

From 1969-71 several collections were made in the Palnis but this species is now a rarity as the forests giving it shelter are mostly denuded. A single specimen was collected from a shaded stream on the Ootcamund-Naduvattom road in the Nilgiris in 1992.

Distribution: N.W. and N.E. India, Nepal, Sri Lanka, Bhutan, Sumatra, Java, the Philippines, S.W. China, Fiji.

9. *Cheilanthes viridis* (Forssk.) Sw.

Seen frequently on exposed roadsides at Upper Kothayar at 1500 m. It can be confused with *Pellaea boivini* but, as pointed out by Sledge (1982), the pinna insertions are different in not being articulated and the segments are more cuneate based.

Distribution: South India, Sri Lanka, Southern Africa, Mauritius, Réunion. Probably an adventive alien in Sri Lanka and S. India.

10. *Colysis hemionitidea* C. Presl

A species with simple, petiolate fronds and slight elongated sometimes partly confluent sori. Collected from several forests in the Anamallays from 900 to 1300 m. It is only found on fully shaded stream-banks.

Distribution: N. India, Nepal, Bhutan, Bangladesh, Malay Islands.

11. *Cyathea crinita* (Hook.) Copel.

Of the three species of Cyathea in South India, the other two being *C. nilgirensis* Holttum and *C. gigantea* (Wall ex Hooker) Holttum, this is the rarest, growing in streams at 2200 m in the Palnis and Nilgiris. Also seen in Silent Valley, near Munnar in Kerala. This fern is also cultivated in the fernery of Sacred Heart College, Kodaikanal, its densely pale-scaley stripe and rachis making it a most handsome, robust tree-fern, which is capable of surviving frosts.

Distribution: South India, Sri Lanka .

12. *Diplazium beddomei* C.Chr.

This species with shallow lobes on simple pinnules was collected from two places in Tamil Nadu; Agasthiamalai (1500 m) and Upper Kothayar (1500 m). In both places it occurs on completely shaded stream-banks.

Distribution: Endemic to South India and Sri Lanka. Sledge (1962) reported it only from Sir Lanka.

13. *Diplazium cognatum* (Hieron.) Sledge

This species was observed on the eastern and southern slopes of the Palnis at 1100 m during 1971 but is now apparently totally absent there. However several plants were recently recorded in the Sheikal Mudi forests in the Anamallays (1300 m).

Distribution: Endemic to South India and Sri Lanka. Sledge (1962) reported it only from Sri Lanka.

14. *Dryopteris juxtaposita* Christ

It occurs on exposed stone-walls and among bushes on the high plateau of the Nilgiris (2300 m), It was collected in 1970 from the periphery of a shola near Munnar at 1800 m. A few plants were also found growing on stone walls at the entrance of La Providence in Kodaikanal at 2300 m. Fraser-Jenkins (1989), who first recorded it from S. India found it quite commonly west of Kotagiri in the Nilgiris and near Kodaikanal int he Palnis

Distribution: North India, Nepal, Bhutan, S.E. Tibet, S.W. China, Thailand, Vietnam.

15. *Elaphoglossum nilgiricum* Krajina ex Sledge

Two plants were collected by the author at Muzhiar in Kerala at 900 m and it grows abundantly in a shola near T.R.Bazaar in the Nilgiris (2300 m). Two more records were made from Akkamalai Forests in the Anamallays (1700 m). It is to be noted that this species was recorded as terrestrial in Muzhiar and as epiphytic in the Nilgiris and Anamallays.

Distribution: Endemic to South India.

16. *Grammitis attenuata* Kunze

A very small lithophyte seen at the edges of forest streams from 800 m in the Ponmudi Hills, Kerala, up to 2300 m in the Palnis. This species is likely to disappear from the Western Ghats as its specialised, highly moist habitat is badly affected by the destruction of sholas.

Distribution: Endemic to South India and Sri Lanka.

17. *Glaphyropteridopsis erubescens* (Hook.) Ching

Seen in two localities. One was on an exposed stream-bank on the Sholayar-Chalakudi road in the Anamallays at 1200 m, although these particular plants are likely to be crowded out by the surrounding quick-growing flowering plants. The second was on a moist but exposed road-side in the Mahendragiri forest at about 900 m.

Distribution: N. & S. India, Nepal, Bhutan, S.E. Tibet, China, Taiwan, the Malay Peninsula and Islands.

18. *Helminthostachys zeylanica* (L.) Hook.

Has been observed by the author only in two localities, a Coconut groove in Thruvallam, Trivandrum and at Keeriparai near Nagercoil, Tamil Nadu, at sea level. These two localities are both in inhabited areas.

Distribution: N. India (from northern Pradesh easwards), Sri Lanka, Malay Peninsula, China, Japan, the Philippines, Solomon Islands, New Caledonia, New Guinea, Australia.

19. *Humata repens* (L.f.) Diels

An extremely rare species collected by the author only from two localities, Muzhiar at 900 m and Kothayar at 1500 m. In Muzhiar it was an epiphyte whereas in Kothayar it was a large colony on a partially exposed rock in the middle of a stream.

Distribution: South-east India, Malay Peninsula, and Islands, Australia, China, Japan, Mascarene Islands.

20. *Hypodematium crenatum* (Forsk.) Kuhn subsp. *crenatum*

A wide spread old-world species, although only two records have been made by the author in South India: one on an exposed stone wall at the entrance to Pannaikadu, in the Palnis, at 1400 m and another on the roadside at Yercaud Tamil Nadu. Fraser-Jenkins (nos. 9125-9127, BM) found it more commonly in the Shevaroy Hills below Yercaud in 1978. It prefers a calcareous substrate and is less common in its absence.

Distribution: C. India, The Himalaya, Nepal, Sri Lanka, S. China, Malay Peninsula, Indonesia, E. Africa, Mauritius, Madagascar, Cape Verde Islands and Pacific Islands.

21. *Hymenophyllum* (*Mecodium*) *denticulatum* Sw.

Only a single site for this lithophyte is known to the author, on an exposed stream in a dry-deciduous forest near Chalakudi in Kerala at 500 m. and Sledge (1968) also reported it from only a single S. Indian collection.

Distribution: India (Meghalaya, Kerala), Bhutan, Myanaung (Burma), Java.

22. *Hymenophyllum* (*Mecodium*) *javanicum* Spreng.

Collected by the author from a single locality at Agasthiamalai (1500 m), growing on the side of a bridle path in the evergreen forest.

Distribution: N. & S. India, Sri Lanka, Myanaung (Burma), Malay Peninsula, the Philippines, Mauritius, Réunion, Australia, New Zealand.

23. *Lastreopsis tenera* (R.Br.) Tindale

Collected by the author in 1969 in the Vellagavi dry deciduous forest at 1100 m on the southern slopes of the Palnis but not now seen here. However it also occurs abundantly in the evergreen forest of the Kalakad hills at 1000 m.

Distrlbution: South India, Sri Lanka, the Phillppines, Indonesia, Taiwan, N. Australia, New Caledonia, Fiji.

24. *Leptochilus thwaitesianus* Fée

This species is typically found on well shaded stream-banks in sholas from 1500 to 2000 m. It was collected by the author from a shola at Devikolam (1500 m) and Grass Hill (1800 m). Unlike *L. decurrens*, which occurs gregariously, this species is always solitary or only forms a small colony. Its distinction from narrower forms of *L. decurrens* has been expounded in detail by Sledge (1956).

Distribution: C. & S. India, Sri Lanka, Myanaung (Burma).

25. *Lindsaea malabarica* (Bedd.) Baker ex C.Chr.

A single plant of this was seen in the Upper Kothayar valley (1500 m). However, it grows gregariously in a single spot in the Mathikettan shola of the Kolli hills at 1200 m in Tamil Nadu. It was not seen by the author anywhere else in the Western Ghats.

Distribution: Endemic to South and S.C. India (Madhya Pradesh and Tamil Nadu).

26. *Metathelypteris flaccida* (Bl.) Ching

The only locality found by the author in the Western Ghats is the Upper Kothayar valley (1500 m) in the Tirunelveli hills in Tamil Nadu, where it grows on partially shaded stream-banks.

Distribution: India (South India, Himalaya), Nepal, Sri Lanka, Java, the Philippines, S. China.

27. *Microlepia majuscula* (Lowe) T. Moore

Beddome (1864) recorded it from the Anamallays. Two new collections have been made from the Palnis: on a cardamon estate on the southern slopes (1200 m) and at Perumal Peak shola on the eastern slope. This species is under cultivation in the Sacred Heart College fernery at Kodaikanal. It was omitted by Dixit (1984).

Distribution: Endemic to South India and Sri Lanka.

28. *Microlepia platyphylla* (Don) J.Sm.

A beautiful and rare species with large, elongated-triangluar, coarse segments and tall fronds recorded by the author from two places in the Palnis: Perumal peak shola (1700 m) and Vellagavi (1200 m).

Distribution: South India, Nepal, Sikhim, Bhutan, Sri Lanka, Myanaung (Burma).

29. *Microlepia strigosa* (Thunbg.) C. Presl

Occurs sporadically in the dense forests of the Tirunelveli Hills at 1500 m. A single plant was seen on the stream-bank in Lamb's Rock shola (1800 m) in the Nilgiris.

Distribution: N. & S. India, Nepal, Bhutan, Sri Lanka, the Malay Peninsula, and Islands, Polynesia, China, Taiwan, the Philippines, Japan, Korea, Fiji.

30. *Oleandra musifolia* (Bl.) C.Presl

In the Palnis it occurs gregariously and the author has found it almost entirely covering a huge semi-exposed rock in Tiger shola (1700 m.). In 1986 he recorded it from Idliar forest in the Anamallays (1200 m) and more recently in Sheikal Mudi forest in the Anamallays at 1200 m. It was also collected from a rock on a stream-bank by the Naduvattom-Gudalur road in the Nilgiris. This species prefers partially exposed habitats and may be on the increase since the forest began being cleared.

Distribution: South India, Sri Lanka, extending to Java.

31. *Ophioglossum reticulatum* L.

The only record made by the author is from the edge of Berijam lake (2300 m) in the Palnis where it was seen as a colony among *Pteridum reticulatum* (Bl.) Nakai, the common bracken of India. It has been widely mis-reported as being *O. vulgatum* L., which does not occur in India. A range of morphology occurs between the present species and *O. petiolatum* Hook., which is usually treated as being merely a form of *O. reticulatum*

Distribution: India (Central India, Himalaya and S India); Nepal, Bhutan etc. pantropical.

32. *Osmunda hugeliana* C. Presl.

This species was seen as an extensive colony along the tributaries feeding into Kodaikanal Reservoir (2300 m) although it is now totally eliminated there by the construction of a dam. Another colony was seen on the Berijam-Munnar road in the Palnis and two further records have been made in the Anamallays: Nirar dam and Periyakallar (1200 m). In all cases the habitats are fully exposed. Often reported as *O. regalis* in error, this more delicate species has smaller, shorter pinnules and narrower pinnae.

Distribution: S. India, ? S.E. Asia.

33. *Cyrtomium caryotideum* (Wall. ex Hook. & Grev.) C. Presl.

This species was collected from forests around Top Station in the Palnis (1800 m) in 1969 and later from Gundar shola on the high plateau of the Palnis. A single plant was also collected from a shola on the Ootcamund-Avalanche road in the Nilgiris (2300 m).

Distribution: N. Pakistan, N. & S. India, Nepal, Bhutan, China, Taiwan, Vietnam, Japan.

Fraser-Jenkins (pers. comm. 1995) points out that he collected a distinct species with smaller, less toothed or auriculate pinnae in the Shevaroy Hills, N.W. of Yercaud, in 1978. He recognises this as *C. micropterum* (Kunze) Ching., a species near to *C. divicola* (Mak.) Tag. from Japan and China; it occurs in S. India, E. Africa, Cameroon and Madagascar.

34. *Pleopeltis macrocarpa* (Bory ex Willd.) Kaulf.

A high-altitude epiphyte on the high plateau of the Palnis (2300 m). Also observed as an epiphyte in a shola on the way to Terrace Estate in the Nilgiris.

Distribution: Endemic to South India and Sri Lanka.

35. *Polystichum subinerme* (Kunze) Fraser-Jenkins

The only locality by the present author is from the shola at the top of Agasthiamalai (1600 m) where it grows on partially shaded stream banks. Fraser-Jenkins (nos. 9037-9041, 9083, 9084, B.M.) found it commonly in the Shevaroy Hills, N.W. of Yercaud in 1978.

Distribution: Endemic to Southern India.

36. *Pronephrium triphyllum* (Sw.) Holttum

During the author's survey of the Western Ghats, the only record made was from the Upper Kothayar hills (1500 m) where it grows under trees and along stream-banks forming a colony.

Distribution: N. & S. India, Bangladesh, Sri Lanka, Myanaung (Burma), Thailand, China, Taiwan, Japan, Malesia, Queensland (Australia), the Philippines.

37. *Pteris geminata* Agardh

This species is a large and beautiful fern which the author has seen growing in Kalakad forest (1100 m) and in the forests between Sholayar Dam and Chalakudi in the Anamallays at 1200 m.

Distribution: Endemic to South India.

38. *Pteris mertensioides* Willd.

Only two localities for this elegant large species are known to the author: one from forest between the Sholayar Dam and Chalakudi and the other from Nadugani forest in the Gudalur range in the Nilgiris at 1200 m.

Distribution: S.India, Sri Lanka, Borneo, the Philippines, Society Islands.

39. *Pteris multiaurita* Ag.

A single record of this species was made by the author from the Karaiar-Kannikatty road in a partially exposed site at 600m in the Tirunelveli Hills. In a remarkable research study, Walker (1958) found that *P. multiaurita* is fully interfertile with the quite unrelated species, *P. quadriaurita* Retz., from Sri Lanka and S. India, the fertile diploid sexual hybrids may be so numerous as to dominate and crowd out the parents and have been named *P.* x *otaria* Bedd., with intermediate frond morphology.

Distribution: Endemic to South India.

40. *Pteris vittata* L.

Collected in 1969 from an exposed stream bank at the foot of the northern slope of the Palnis(400 m) and again from the fully exposed roadside at Upper Kothayar Dam.

Distribution: Ubiquitous throughout the tropics and subtropics of the old world, forming a semi-cryptic cytological complex of diploids, tetraploids and triploid hybrids.

41. *Schizaea digitata* (L.) Swartz

The only record made by the author is from a deciduous forest at the tropical Botanical Garden, Palode; Trivandrum, where it grows as a colony on the forest floor at 700 m.

Distribution: South India, the Malay Peninsula, Philippines, Australia, New Zealand, Polynesia, the Mascarene Islands, tropical America, the West Indies.

42. *Thelypteris confluens* (Thunb.) Morton

Beddome recorded this species from Perumalmalai in the Palnis at 1600 m. The present author collected it from the same locality in 1969, which is now completely overgrown with

Lantana. However, this species also grows among grasses and sedges at the periphery of Berijam lake at 2300 m.
Distribution: South India, Thailand, Laos, Malesia, New Zealand, Africa.
43. *Vittaria flexuosa* Fée

Collected from a tree on the stream-bank of a shola on Mackay's Path in the Anamallays (2000 m) and again from Kolli hills at 1200 m. A very rare epiphytic species.
Distribution: N. & S. India, Sri Lanka, Nepal, Bhutan, Thailand.
44. *V. microlepis* Hieron.

This species was seen at the base of a large tree in the coffee-plantation in Manalur in the Palnis, at 1100 m. A second record is from the Agasthiamalai forest (1200 m).
Distribution: Endemic to South India and Sri Lanka. Sledge (1982) reported it only from Sri Lanka.

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ON THE ECOLOGY AND POPULATION DYNAMICS OF A DUTCH POPULATION OF *POLYSTICHUM SETIFERUM* (DRYOPTERIDACEAE: PTERIDOPHYTA)

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Key words: ecology, Noordoostpolder, Netherlands, *Polystichum setiferum*

ABSTRACT

The ecology and population dynamics of a population of *Polystichum setiferum* (Forssk.) Woynar have been surveyed in the Kuinderbos. This area, situated in the Noordoostpolder, reclaimed from the former Zuiderzee, harbours 95% of the Dutch population. These ferns grow on calcareous sands on ditch banks under a canopy of *Fraxinus excelsior* L., *Picea sitchensis* (Bong.) Carrière or *Fagus sylvatica* L. The ecology of the species changed during 15 years in view of exposure and composition of the canopy. At other sites in the Ijsselmeerpolders, i.e. the areas reclaimed from the Zuiderzee, the species thrives on ditch banks on clayey soils under deciduous species.

Individuals were mapped and monitored for 15 years. There was an increase in population, although severe winters reduced survival and growth. The Kuinderbos population has a high recruitment compared to other populations in the Atlantic region. Young plants appeared in the spore shadow of adult plants. *Polystichum setiferum* is able to colonize newly planted woods between 10 - 15 years after planting.

INTRODUCTION

Polystichum setiferum has only recently become known in the Netherlands. In 1956 material, named as *Polystichum aculeatum* (L.)Roth., was collected in the Savelsbos (Limburg), in the most southern part of the Netherlands. In 1979 the material was revised and correctly identified (Heukels & de Graaf 1979). In the same year the species was found in the Kuinderbos, one of the woods laid out in the Noordoostpolder. The Kuinderbos is considered to be the richest area for ferns in the Netherlands. After 1979 the total number of fern taxa known from this locality increased to 27, with first records of various taxa (Bremer 1980, 1988). Since 1978, populations of rare species have been monitored, some of them annually, others less frequently (Bremer 1994).

The question is under which ecological circumstances *Polystichum setiferum* is able to grow in the Kuinderbos. A monitoring programme was started at the Kuinderbos to ascertain the development of this and other rare species. Since many fern species are growing here under - by Dutch standards - unique circumstances we wondered if these populations would be able to maintain themselves and we were also interested in the factors influencing the size of the population. Moreover, we wanted to reconstruct the process of colonization.

THE STUDY AREA

In 1932 the Zuiderzee was closed, and since then four polders were reclaimed: Wieringmeerpolder (1933), Noordoostpolder (1942), Oostelijk Flevoland (1958) and Zuidelijk Flevoland (1969). In these polders over 15,000 Ha of woods were planted. These woods were planted on poor soils in the oldest polders but in both Flevoland polders they were laid out especially on clayey soils. Various tree species were planted, especially *Pinus nigra*, *Picea abies*, *Populus* x *canadensis*, *Quercus robur*, *Fraxinus excelsior*, *Fagus sylvatica* and *Acer pseudoplatanus*, depending on substrate, drainage and the forestry management philosophy at the time.

The Kuinderbos differs from all the other woods in having a "peat erosion area", where peat has been partially eroded, and the potholes were filled in with fine-grained sand. Ditches were

dug with a density of up to 0.7 km per Ha. Their depth ranges from 0.3 to 1.6 metres. The phreatic level is usually below the bottom of these ditches. On ditch banks the fine-grained, calcareous sand is exposed (figure 1). The ferns of all woods were surveyed between 1979 and 1994.

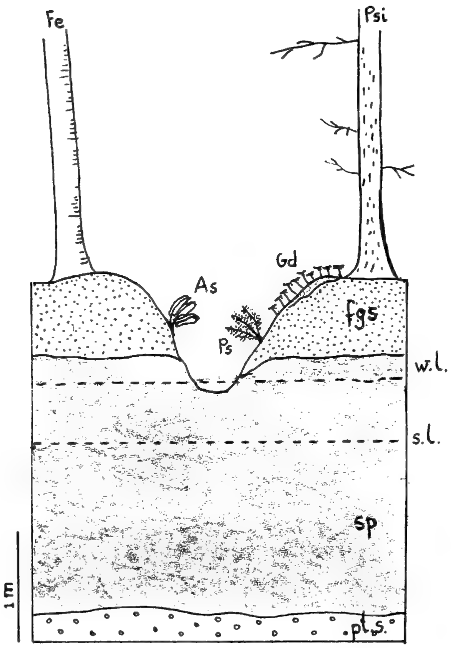

Figure 2.
Distribution of *Polystichum setiferum* in the Netherlands (1979 - 1993).

Figure 1. The ditch bank habitat of *Polystichum setiferum* (Ps) and other rare ferns (As = *Asplenium scolopendrium*, Gd = *Gymnocarpium dryopteris*) in the Kuinderbos (The Netherlands). Psi = *Picea sitchensis*, Fe = *Fraxinus excelsior*, fgs = fine grained sand, sp = sphagnum peat, pl.s = pleistocene sand, w.l = phreatic level (winter), s.l = phreatic level (summer).

METHODS

From 1979 onwards all ferns in the Kuinderbos were mapped. The number of fronds per plant (n), the number of fertile fronds per plant (n_f) and the maximal size of fronds per plant (L_{max}) were measured annually in two plots at the end of the summer. The whole Kuinderbos population was surveyed in this way in 1979, 1984, 1990 and 1993. In 1979 and 1993 the habitat was described in terms of substrate, canopy composition, depth of ditches, exposure and inclination. Twelve populations were examined in the UK and Belgium in terms of population structure (n, n_f, L_{max}) and habitat. This information had to be used as a reference in view of the limited age of the Dutch populations.

ECOLOGY OF *POLYSTICHUM SETIFERUM*

In the Kuinderbos the ferns are linked with ditch banks in the "peat erosion area" (X^2=158.9 p< 0.001). They grow on a topsoil of fine calcareous sand overlying peat. *Fagus sylvatica* and *Picea sitchensis* dominated the canopy in 1979, *Fraxinus excelsior* being more important in 1993 (X^2=35.8 , $p < 0.001$). The ferns are growing in moderately deep ditches (0.5 - 1 m deep). In shallow ditches (< 0.5 m) the layer of fine sand is too thin for successful establishment. In 1993, the ditches in which ferns were established were shallower on average than in 1979 (t = 4.6, $p < 0.05$). The ferns are growing over the whole range of the ditch banks. The ferns growing

on the lower part of the banks are apparently able to survive a short period with a high phreatic level. There was no difference in relative height between 1979 and 1993 ($t = 0.6$, n.s). In 1979 the plants preferred a NE exposure ($X^2=28.4$, $p <0.001$); no preference was observed in 1993 ($X^2=3.1$, n.s) (table 1).

	Kuinderbos		1979 n=59	1993 n=128
substrate	fine sand	31	56	128
	podzol	27	-	-
	peat	20	-	-
	clay	8	3	-
	other	14	-	-
			$X^2=158.9$	$X^2=284.7$
			$p < 0.001$	$p < 0.001$
canopy	*Fagus*	<1	44	36
compostion	*Fraxinus*	19	8	57
	P. sitch.	7	7	34
	P. abies	25	-	1
	Quercus	28	-	-
	Acer ps.	5	-	-
	other	14	-	-
			$G_3=336.6$	$G_3=184.6$
			$p < 0.001$	$p < 0.001$
depth of ditches (cm)			88.2±16.2	75.5±20.0
(min. - max.)			50-160	30-130
			$t=4.6$	
			$p < 0.05$	
relative height			0.46±0.16	0.46±0.25
(min. - max.)			0.11-0.88	0-1.0
			$t=0.6$ n.s	
exposure	NE	50	50	73
	SW	50	9	54
			$X^2=28.4$	$X^2=3.1$
			$p<0.001$	n.s

Table 1
The ecology of *Polystichum setiferum* in the Kuinderbos, the Netherlands, as ascertained in 1979 and 1993. The first column gives the percentages for the Kuinderbos for substrate, canopy and exposure of ditch banks. relative height = distance from ditch bottom to plant/ depth of ditch.

Since 1979 *Polystichum setiferum* has been found on reclaimed soil in five other planted woods in the province of Flevoland as well (figure 2). The number of individuals ranged from 1 - 2 per wood. These were growing on boulder clay (1), sandy clay (2) (Smit 1989), clay (3) and medium fine sand (1), always of a calcareous nature. The canopy consisted of deciduous trees, especially *Fraxinus excelsior* and *Populus* x *canadensis*. The plants were linked with ditch banks, except for one plant on boulder clay.

Elsewhere in the Netherlands solitary plants of this species have been found on a wall at Den Haag and at a well near the Bunderbos in Z.-Limburg (van der Meijden & Holverda 1991, pers.comm. A.Koster) (Figure 2).

POPULATION STRUCTURE AND POPULATION DYNAMICS

Kuinderbos

The population in the Kuinderbos varied from 59 plants in 1979 to 128 plants in 1993, representing 95% of the current Dutch population. Of the 1979 population, only 10% was still alive in 1993 (figure 3a). The maximum size of fronds increased after 1987 (figure 3b). Of the 1979 population 75% of the plants were concentrated at one site of ca. 3m^2 (plot 1), the other plants growing solitary at scattered sites. There were only 8 adult plants. The population was at a mininum in 1987 (18 plants), but increased from 1989/90 onwards. In 1993 87% of the plants were growing at five sites in the spore shadow of an adult plant (figure 4). One of these sites was monitored annually (plot 2, figure 5). Since 1979 the percentage of adult plants increased (34.4%, table 2).

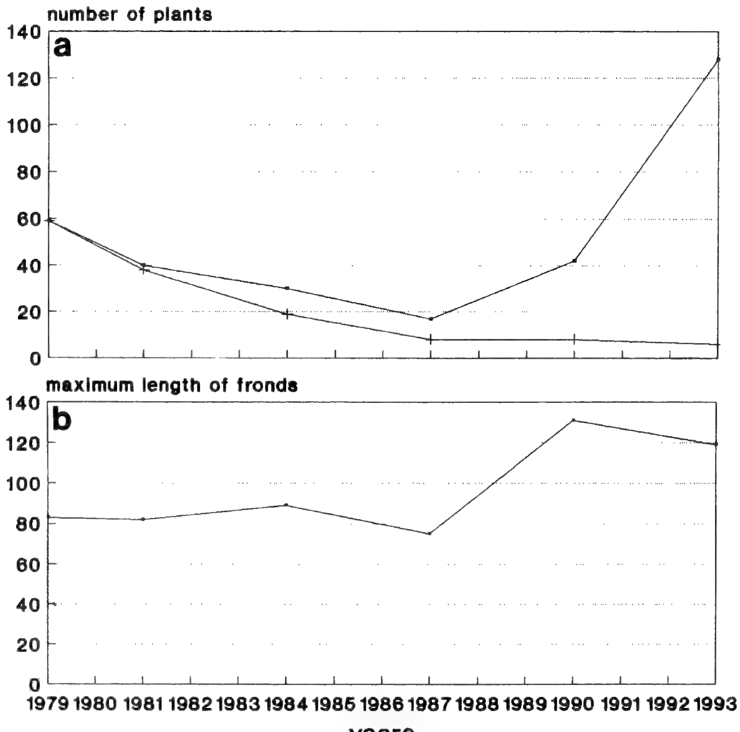

Figure 3.
a. —.— the number of plants in the surveyed Kuinderbos during 15 years.
—+— the number of plants from the 1979 cohort
b. The maximum size of fronds, all fronds taken into account.

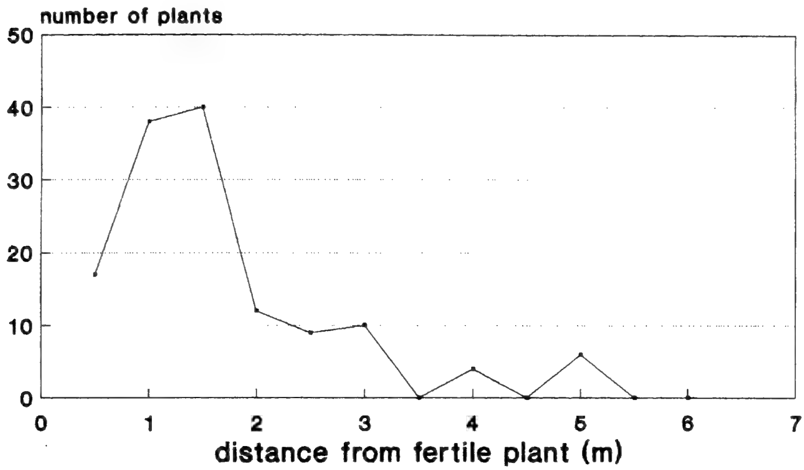

Figure 4.
The distance effect between recruitment and solitary adult (fertile) plants.

	Kbos 1979	Kbos 1993	Dev/Wales	N.Ireland	Belgium
npop	5	8	6	5	1
n	61	128	395	176	54
an ± s	4.4±3.7	6.3 ± 4.9	7.8 ± 6.2	6.8 ± 7.2	7.2 ± 6.4
range	1 - 19	2 - 40	1 - 45	1 - 51	3 - 32
an_f ± s	0.85 ± 2.1	1.8 ± 4.2	5.2 ± 5.5	3.7 ± 6.4	5.4 ± 6.3
range	0 - 9	0 - 28	0 - 40	0 - 40	0 - 28
%nf	9.8 ±41.5.	32.6 ± 25.3	54.8 ± 42.5	35.0 ± 44.4	61.7 ± 41.5
fn	11.8	34.4	68.6	41.5	75.9
aL_{max}	23.5 ± 20.5	18.3 ± 32.2	66.5 ± 28.1	49.7± 41.2	72.8 ± 27.4
range	2 - 83	4 - 119	2 - 122	1 - 136	6 - 110
%j	26.8	13.3	3.3	22.2	1.8
sub.j	20	38	67	80	100

Table 2
Some characters of the populations surveyed.
npop = number of (sub)populations surveyed, Kbos = Kuinderbos, Dev/Wales = populations in Devonshire/Wales (see appendix). n = number of plants surveyed, an = average number of fronds per plant, anf = average number of fertile fronds per plant, %nf = average percentage of fertile fronds per plant, fn = percentage of fertile plants, aL_{max} = average maximum length of fronds per plant (in cm), %j = percentage of juvenile plants (L_{max} < 8 cm), sub.j = percentage of (sub)population with recruitment.

At plot 1 (in deep shadow cast by *Fagus sylvatica* and *Picea sitchensis*) the number of plants decreased since 1978 and even disappeared after 1988. The average of L_{max} increased to 34 cm (4.3 cm per year); no plants reached the adult stage. At plot 2 (lightly shaded by *Fraxinus excelsior*) recruitment took place in the spore shadow of an adult plant from 1989 onwards. Within four years 61% of the plants reached the adult stage. The average of L_{max} increased with 13.1 cm per year.

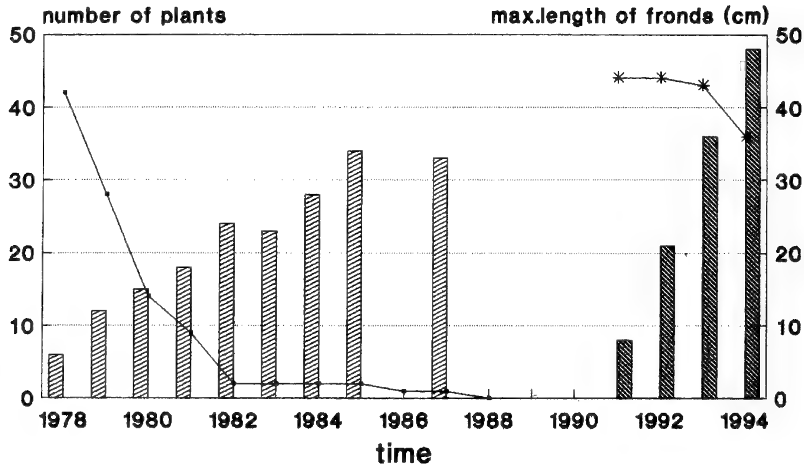

Figure 5.
The number of plants and the average maximum size of fronds (aL_{max}) for two (cohort) populations during 17 years.
.____. number of plants 1978 cohort (Plot 1) *—* number of plants 1990 cohort (Plot 2)

aL_{max} 1978 cohort (Plot 1) aL_{max} 1990 cohort (Plot 2)

Other populations

The average number of fronds per plant (an) does not differ much between the Kuinderbos population (1993) and the UK/Belgium populations. The average of L_{max} is much lower in the Kuinderbos population (1979/1993) as in the other populations. The correlations between n and Lmax are always significant, the Kuinderbos (1993) having nearly the same correlation coefficient as the other populations (table 3). At the Kuinderbos (1979) the percentage of juvenile plants was higher than in other UK populations, except for those of Northern Ireland. A concentration of juvenile specimens was observed in some (sub)populations due to regeneration in the spore shadow of adult plants, but in other (sub)populations there was no recruitment. Therefore the percentage of populations showing recruitment was lower in the Kuinderbos than in the other populations examined.

		n_f	$\%n_f$	L_{max}
	1	–	–	0.70
n	2	0.76	0.43	0.49
	3	0.84	0.33	0.52
	4	0.87	0.46	0.54
n_f	1		–	–
	2		0.79	0.65
	3		0.68	0.65
	4		0.73	0.69
%nf	1			–
	2			0.76
	3			0.69
	4			0.81

Table 3
Correlations between some parameters for the Kuinderbos-population in 1979 (1) and in 1993 (2) and populations of *Polystichum setiferum* in Devonshire/Wye valley (3) and in Northern Ireland (4) (see appendix).
n = number of fronds per plant, n_f = number of fertile fronds per plant,
%nf = percentage fertile plants, L_{max} = maximum length of frond per plant, – = no correlation calculated due to skewness of values. All the correlations are significant ($p < 0.01$).

FERTILITY

The average number of fertile fronds per plant (an_f) increased from 0.8 in 1979 to 1.8 in 1993 and is lower than in other examined populations. The percentage of fertile plants increased over 15 years, but is still lower than that found in UK populations. The average percentage of fertile fronds increased over the same period and equalled that of the populations examined in Northern Ireland (table 2). A relation exists between fertility and the length of the fronds. At the Kuinderbos plants with L_{max} of at least 0.7 m were fertile, except for 1979 when few adult plants were growing in the area. Individuals with $L_{max} < 0.3$ m can be fertile. In the populations examined in the UK, plants with $L_{max} < 0.3$ m were always found to be sterile and it was observed that taller plants ($L_{max} > 0.7$ m) can be sterile as well (figure 6).

DISCUSSION

Ecology: *Polystichum setiferum* is a very rare species in the Netherlands. Living specimens have established in the woods recently laid out in the Noordoostpolder and Oostelijk Flevoland. They are correlated with ditches, calcareous substrates and canopies of various tree species. There was a shift in ecology of the Kuinderbos populations over 15 years with respect to exposure and canopy composition as currently more plants are growing under specimens of *Fraxinus excelsior*. There is more incoming light under *Fraxinus excelsior*.

In the UK the species mainly occurs in deciduous woodland in river valleys, along the streambanks, on lanebanks and in hedgerows (Page 1982). It prefers sloping, permanently slightly moist soil with a pH between 6.5 - 8.0. The Kuinderbos populations fulfil the requirements of slope, pH and moisture since the subsoil of peat supplies the upper layer of fine-grained sand with capillary water (figure 1). Its habitat differs in having *Picea sitchensis* in the canopy. The species is indicated by Dostál & Reichstein (1984) to be acidiophilous, but several

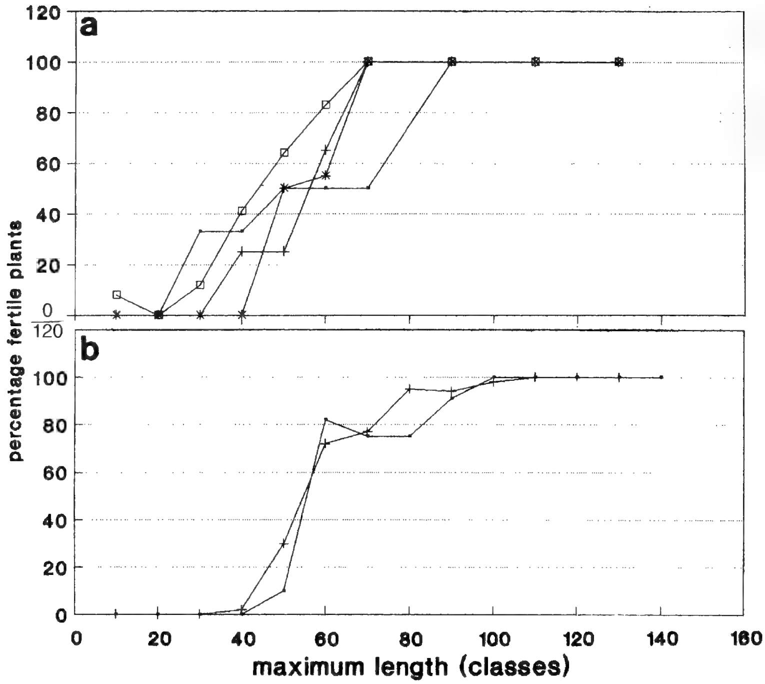

Figure 6
a. The percentage of fertile plants in relation to classes based on the maximum size of fronds per plant for the Kuinderbos population
__.__ 1979 (n = 59), ____ = 1984 (n = 32), —*— = 1990 (n = 42), —[]— = 1993 (n = 128)
b. The percentage of fertile plants in relation to classes based on the maximum length of frond per plant.
___.___ = populations in N.-Ireland
—+— = populations in South Devonshire/Wye valley (England/Wales)

species which are calcicole at the border of their range and not calcicole in the centre are known (Hengeveld 1990). This can even be noted within the UK for *Polystichum setiferum* (Page 1982). Because thousands of Ha of woods have been laid out on clay in Flevoland, the district comprising the polders reclaimed from the Zuiderzee, new sites with *Polystichum setiferum* are to be expected.

Population Structure and Dynamics: In 1979 the Kuinderbos population was young, with only 8 adult plants. We tried to establish when first colonization had taken place. Under heavy shade (plot 1) the average L_{max} increased with 4.3 cm per year, under light shade (plot 2) with 13.1 cm per year. Considering the tallest plant in 1979 (83 cm) this plant may have been between 7 and 19 years old; therefore establishment apparently took place between ca. 10 and 22 years after planting in 1949 - 1951. In Oostelijk Flevoland (Overijsselse Hout) the first individual was established 10 - 15 years after planting (Smit 1989). Although adult plants have a high spore production the recruitment level in the Netherlands is low. Most recruitment takes place in the spore shadow, within 5 m from an adult plant. A high density of spores seems to be necessary for establishment. Established plants suffer from severe winters. In plot 1 36 % of the plants died in the severe winter of 1978/79. After 1980 the number of plants declined to a low level in 1987, negatively influenced by the severe winters of 1984 through 1987, which caused damage to fronds and probably interfered with recruitment. In the Kuinderbos *Polystichum setiferum* is at the northern limit of its mainland European range (Jalas & Suominen 1972), its

range coinciding with January isotherm of 0°C. It does not imply that *Polystichum setiferum* can not tolerate low temperatures for some time, because plants survived temperatures of -23°C in ditches during the winter of 1978/79. Nevertheless in the Netherlands severe winters are found to cause a lot of frost damage (necrosis) to various fern species, for example *Asplenium scolopendrium*.

In the Kuinderbos the plants are smaller than in UK populations due to their more recent establishment. The average number of fronds per plant is nearly the same, even in population with little recruitment, indicating that growth is mainly expressed in the size of the fronds. As Page (1982) stated recruitment in populations in the UK takes place rapidly, often on damp banks where these are exposed by erosion, as was confirmed in this study. In the Kuinderbos many km of ditch bank seem appropiate for calcicolous species as *Polystichum setiferum* due to erosion. On one hand erosion of ditch banks can be a reason for a low chance of establishment and at plot 1 erosion was one of the reasons for the death of plants. On the other hand erosion produces new microhabitats, which are suitable for establishment. Unlike *Polystichum setiferum*, *Asplenium scolopendrium* had a high recruitment in the Kuinderbos during the last 15 years, establishing itself in microhabitats created by erosion.

Fertility: Fertility can be supressed under heavy shade, as indicated for plot 1. In the Kuinderbos the fertility of *Asplenium scolopendrium* could be shown to be diminished by frost damage. Fertile individuals may become sterile after a severe winter. This may have played a role at plot 1 as well. In the UK a high percentage of larger plants can be sterile, while at the Kuinderbos these are always fertile. Probably there is more competition in the UK, since there the species can form stands with up to 4 - 6 adult plants per m^2 with no plants in between due to accumulation of died fronds. Up to 1993 such stands have not been formed in the Kuinderbos.

APPENDIX

The surveyed populations in the UK and Belgium.

United Kingdom

Northern Ireland (July 1993)

-Helen's bay (Crawfordsburn), 5°43′ W 54°39′ N; lane bank under *Acer pseudoplatanus*.

-Crawfordsburn Park, 5°43′ W 54°39′ N; along rivulet in deciduous woodland.

-Crawfordsburn Park, railway bridge, 54°3′ W 54°39′ N; *Acer pseudoplatanus-Fraxinus excelsior-Tilia* woodland.

-Carnalea (Bangor), 5°42′ W 54°41′ N; *Alnus glutinosa - Acer pseudoplatanus* woodland along rivulet.

-Holywood, Redburn County Park, 6°50′ W 54°38′ N; mixed deciduous woodland on slope.

Devonshire (July 1994)

-Redbrook, 2°40′ W 51°48′ N; *Tilia - Ulmus* woodland.

-Tavistock Woodland Estate, 3°40′ W 50°17′ N; *Castanea sativa - Acer pseudoplatanus* woodland in reserve.

-Slapton Wood, 3°39′ W 50°18′ N, *Acer pseudoplatanus* woodland in reserve.

-Slapton, 3°39′ W 50°18′ N; hegdebank between Slapton and Slapton wood.

-Avon, 3°7′ W 50°22′ N; *Acer pseudoplatanus - Fraxinus woodland* along river.

Wales (July 1994)

-Wye valley, Llandago, 2°42′ W 51°43′ N; *Acer pseudoplatanus* woodland.

-Wye valley, Llandago, Gleddon Shoots, 2°42′ W 51°43′ N; *Acer pseudoplatanus-Fraxinus excelsior-Tilia* woodland.

Belgium (July 1987)

Ardennen, Comblain au Pont, 5°65′ E 50°45′ N; *Acer pseudoplatanus-Fraxinus excelsior-Tilia* woodland along Ambléve.

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THE ECOLOGY AND CYTOLOGY OF *BRAINEA INSIGNIS* (BLECHNACEAE: PTERIDOPHYTA)

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Key words: *Brainea insignis*, Malaysia, cytology, ecology

ABSTRACT

A chromosome count of n = 35 is recorded for the Malaysian cytotype of the monotypic genus *Brainea* thus providing further information on the cytological position of the genus in particular and the family (Blechnaceae) in general.

INTRODUCTION

Holttum (1966) grouped *Brainea* (Hk.) J. Smith together with *Blechnum* L. and *Woodwardia* J. Smith under the Sub-family Blechnoideae of the Dennstaedtiaceae in his treatment of the Peninsular Malaysia blechnoid ferns. Among the common principal characters of the sub-family are: rhizome short, stout, erect or nearly so; fronds simply pinnate with unlobed or rarely lobed pinnae, sterile and fertile pinnae of same shape or the fertile pinnae very narrow; veins free except for a series of narrow costal areoles in *Woodwardia* and in fertile fronds of *Blechnum indicum*; sori close to the midrib, linear, each protected by an indusium along its outer side, in *Brainea* without indusium. However other authors mostly raised the sub-family rank of all blechnoid ferns into the family level - Blechnaceae - on the ground of (among other characters) having the unfolding leaves tinged with red due to the presence of 3-deoxyanthocyanins.

Tryon and Tryon (1982) mentioned nine genera and c. 175 species for Blechnaceae of which three are Tropical American (*Woodwardia*, *Blechnum* and *Salpichlaena*). Among the genera shared with the Old World are *Blechnum* and *Woodwardia*. Other genera confined to the Old World but which are absent in Malaysia are *Doodia* R.Br., *Pteridoblechnum* Hennipm. and *Sadleria* Kaulf. Most of the authors including Tryon and Tryon (1982) and Lovis (1977) placed *Stenochlaena* under Blechnaceae, whilst Holttum (1966) grouped it together with *Pteridium*, *Histiopteris*, *Pteris* and *Acrostichum* under Sub-family Pteridioideae of Dennstaedtiaceae.

Lovis (1977) listed eight genera under the fern family Blechnaceae omitting *Diploblechnum* Hayata. These are *Blechnum*, *Salpichlaena*, *Doodia*, *Brainea*, *Sadleria*, *Woodwardia* (incl. *Lorinseria*), *Pteridoblechnum* and *Stenochlaena*. The chromosome base numbers for these genera ranged from 28 to 40 with Blechnum showing an extensive aneuploid series in a sequence from 28 to 36, ie. 28, 29, 31, 32, 34, 36 (and c.37).

DISTRIBUTION AND ECOLOGY

Brainea is a monotypic genus, comprising the single species, *Brainea insignis* (Hk.) J.Sm. Holttum (1966) noted that this sole species is distributed from the Khasya hills eastwards to Southern China and southwards to Tenasserim, Siam, Malaya and Northern Sumatra. He further noted that the species could only be found in three locations in Peninsular Malaysia, ie. on the summit of Gunung Terbakar, Cameron Highlands, on rocky headlands of Tanjung Selantai, Johor and in Pulau Sembilan, Perak. Gunung Terbakar referred to by Holttum might have been one of the summits found in the Cameron Highlands area of the Main Range, while Pulau Sembilan are the numerous islets around Pulau Pangkor; the main island being not far from the coast of Perak State, west of Peninsular Malaysia.

Figure 1. *Brainea insignis* on the seaside headland of Tanjung Selantai Johor.

Figure 2. *Brainea insignis* grown at the UKM Fern Garden.

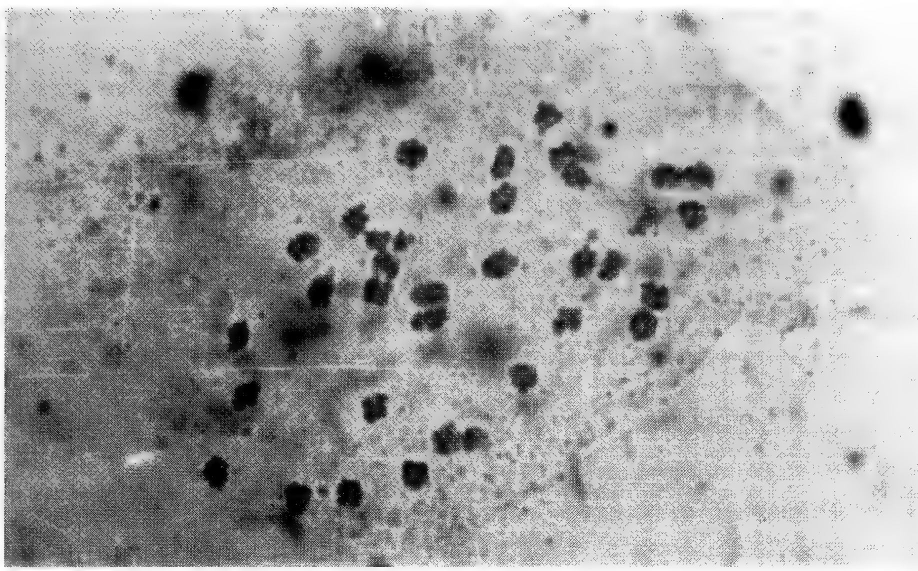

Figure 3. Meiosis in *Brainea insignis* showing 35 bivalents, x1000. Acetocarmine squash preparation. Plant collected from the only known locality in Malaysia, Tanjung Selantai Johor, and grown in Universiti Kebangsaan Malaysia Fern Garden, Bangi.

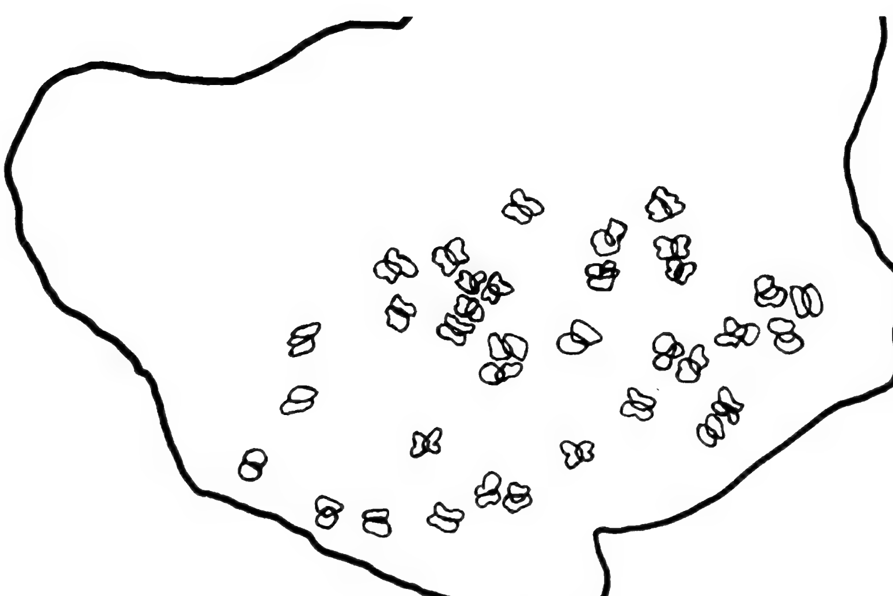

Figure 4. Explanatory diagram of figure 3 showing 35 chromosome pairs in a diploid specimen.

Past records kept at the local herbaria in Malaysia, and also botanical studies carried out extensively by the author in these areas revealed that the species is only found in a small population in Tanjung Selantai, Johor, on the southeastern coast of Peninsular Malaysia. From a population of about 50 plants observed in 1985 the number has dwindled down to less than 10 plants, due mainly to casual clearance of the vegetation on the headland. Figure 1 shows the locality on the rocky headland of Tanjung Selantai where the species was observed by the author in 1985. Several plants had been collected in 1988 and brought back to the Universiti Kebangsaan Malaysia (UKM) Fern Garden in Bangi for conservation purpose and the species had adapted well (Figure 2).

CYTOLOGY

Cytologically the fern family Blechnaceae shows a wide range of basic chromosome numbers with 28 being the lowest number found in *Blechnum* whilst the highest is 40 found in the Tropical American genus, *Salpichlaena*. *Blechnum* shows an array of basic chromosome numbers in an almost unbroken sequence from 28 to 36. Walker (1973) postulated the primitive number in *Blechnum* could be 33 as found in *Brainea* and *Sadleria*. Thus, substantial aneuploid changes occur in the genus. Lovis (1977) also noted *Brainea* with the base number of 33 and *Woodwardia* with two base numbers, ie. 34 and 35.

Fixations were made on *Brainea insignis* grown at the UKM Fern Garden and gave excellent meiotic preparations, one of which is illustrated in Figs. 3 & 4 and showing n = 35 with clarity. Thus, the present study reveals the existence of two base numbers for the monotypic genus *Brainea*, ie. 33 (from established earlier records) and 35 through this investigation.

The locality and morphological attributes for the cytotype (n=33) listed by Lovis (1977) is not known. It is evident that here at least two different cytotypes exist in *B. insignis* so far. It should be pointed out that a better and clearer picture would emerge if more cytotypes from other geographical areas such as Thailand, Southern China and Sumatra become known.

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PROGENY STUDIES OF THE FERN HYBRID *POLYSTICHUM* x *BICKNELLII* (DRYOPTERIDACEAE: PTERIDOPHYTA)

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Key words: *Polystichum bicknellii*, hybridization, allopolyploidy, meiosis.

ABSTRACT

Polystichum x *bicknellii* (Christ) Hahne is a triploid interspecific hybrid of the diploid *P. setiferum* (Forsskål) Woynar and the allotetraploid *P. aculeatum* (L.) Roth. A detailed study is presented of the meiotic division and spore formation of this hybrid. Meiosis is highly irregular and a maximum 2-3% of the spores can germinate, and only a fraction of these develops further.

From approximately 3.7 million spores 155 sporelings were raised, but almost 50% of them were unable to survive. The sporophytes raised are very different morphologically. Sixty-three of the 84 surviving sporophytes were checked cytologically and of these 59 proved to be hexaploid (2n=246) and four to be triploid (2n=123). The hexaploid plants showed almost normal meiosis with some univalents and multivalents, while meiosis in the triploid progeny was a completely disturbed process.

It is assumed that similar processes could also happen in nature, resulting in sexual hexaploid and perhaps triploid apogamous species.

INTRODUCTION

Interspecific plant hybridization usually results in sterile F1 plants. The sterility is often chromosomal, a consequence of disturbed meiosis and failure of pairing due to the partial or total absence of synapsis between homologous chromosomes. This type of sterility can be overcome by polyploidy. In ferns many such cases has been reported both in nature and the laboratory (For example : *Asplenium lepidum* C. Presl, Brownsey 1976a; *A. creticum* and *A. haussknechtii* Godet & Reuter, Brownsey 1976b; *A.* x *lessinense*, Rasbach *et al.* 1979; *A. adulterinum* Milde, Lovis & Reichstein 1968; *Phyllitis hybrida* (Milde) C.Chr., Vida 1963, 1965; 1973; *Cheilanthes fragrans* (L. fil.) Swartz, Vida *et al.* 1983; *Polystichum aculeatum*, Sleep 1966). The fern genus *Polystichum* contains four species in Europe. The base number is x = 41 (Manton 1950), and this has been confirmed by further chromosome counts (Mitui 1975, Daigobo 1972, 1973, 1974, Mehra 1961, Ghatak 1963, Löve & Löve 1961, Löve & Solbrig 1964, Taylor & Lang 1963, Wagner 1973).

The genomic relationship of the four European species appears to be as follows:
Two morphologically and ecologically distinct diploid species, the simply pinnate alpine-montane *P. lonchitis* (L.) Roth and the 2- to 3-pinnate Atlantic-Mediterranean *P. setiferum* (Forsskål) Woynar, have given rise to the allotetraploid *P. aculeatum* with more or less intermediate habitat and pinnation. The fourth European species *P. braunii* (Spenner) Fée is also tetraploid with uncertain origin and genomic composition (Manton 1950, Meyer 1960, Manton & Reichstein 1961, Sleep & Reichstein 1967, Vida 1966, 1972). Sleep (1966) made several attempts to resynthesize *P. aculeatum* from the diploid hybrid of *P. lonchitis* and *P. setiferum*. However the morphology was not in complete agreement with the expectations (see also Vida & Pintér 1981).

Triploid hybrids between the allotetraploid *P. aculeatum* and both of its suspected diploid progenitors have often been found in nature, where the species come into contact. The name *P.* x *illyricum* (Borbás) Hahne was given to the combination of *P. aculeatum* and *P. lonchitis*, while *P.* x *bicknellii* (Christ) Hahne refers to the cross between *P. aculeatum* and *P. setiferum*. In both

cases roughly 41 pairs and 41 univalents have been observed at meiosis, in accordance with the allopolyploid origin of *P. aculeatum* (Manton 1950). The bivalents are formed between chromosomes of the diploid species and one of the genomes of the tetraploid. Using the genomic symbol "L" for one genome of *P. lonchitis* and "S" for *P. setiferum*, the three European species (disregarding *P. braunii*) and their hybrids can be designated as follows:

P. lonchitis LL diploid species	*P.* x *lonchitiforme* LS diploid hybrid
P. setiferum SS diploid species	*P.* x *illyricum* LLS triploid hybrid
P. aculeatum LLSS allotetraploid species	*P.* x *bicknellii* LSS triploid hybrid

The fertility of *P.* x *illyricum* was studied by Vida and Reichstein (1975). In spite of the highly irregular meiotic division of this hybrid, some viable spores were found. Fifteen F2 progeny were cytologically tested. Most of them proved to be hexaploid or triploid. A single diploid and a tetraploid were found also, but their origin by contamination could not be excluded.

A similar but statistically more reliable investigation has been carried out with *P.* x *bicknellii*, the other triploid hybrid. We wanted to study the fertility and its role in possible interspecific introgression between *P. setiferum* and *P. aculeatum.*

Name	Locality	Collector
P. setiferum	Villányi Hills near Bisse LAT:45°40′N, LONG:18°15′E 200 m. above S.L.	I. Pintér
P. setiferum	Bakony Hills, Tót valley near Fenyöfö LAT:47°28′N, LONG:17°45′E 260m above S.L.	I. Pintér
P. setiferum	Mecsek Hills near Orfü LAT:46°05′N, LONG:18°10′E 220m above S.L.	I. Pintér
P. lonchitis	Gerecse Hills "Ebgondolta" forest, near Tata LAT:47°40′N, LONG:18°15′E 150m above S.L.	G. Vida
P. x lonchitiforme	Gerecse Hills "Ebgondolta" forest, near Tata	G. Vida
P. aculeatum	Vértes Hills "Mária" ditch near Szár LAT:47°30′N, LONG:18°30′E 200m above S.L.	I. Pintér
P. aculeatum	Bükk Hills "Vadász" valley near Ómassa LAT:48°07′N, LONG:20°37′E 700m above S.L.	I. Pintér
P. x *bicknellii* ("Pol. 1a")	Mecsek Hills "Szuadó" valley near Orfü	G. Vida
P. x bicknellii ("Pos. 2b")	Bakony Hills Tót valley near Fenyöfö	

Table 1. Sources of the fern specimens

MATERIALS AND METHODS

The ferns used for the examinations were collected in their natural habitat (Table 1) and maintained under greenhouse conditions. Spores were collected from the hybrids in the greenhouse. Great care was taken to avoid spore contamination. A young frond was first isolated by pulling it into a cellophane envelope before sporulation began. Later ripe spores were collected and sown in Petri dishes on KNOP medium solidified by 1% agar-agar, and kept in natural light at room temperature.

Mature prothalli covered with antheridia and archegonia were then selected and submerged into distilled water for about three hours (intergametophytic selfing). After fertilisation was accomplished the material was placed on agar. As soon as the developing sporophytes reached a manageable size (2-3cm) they were transferred to soil.

For chromosome counts the root tips were treated with colchicine solution (0.2%), then fixed in a mixture of abs. ethanol : glacial acetic acid 3:1 v/v. Excised roots (1cm) were washed in distilled water, then digested in a solution containing 4% pectinase and 4% hemicellulase for five hours in 37°C . Then the tips of softened roots were rinsed, stained in acetocarmine, and finally squashed according to Manton (1950).

Pinnules bearing sori of the right age were fixed and stained similarly. However pretreatment and softening in this case was not necessary.

RESULTS

The number of root tip mitotic chromosomes of all the species and natural hybrids were in accordance with the expectation and literature (Fig. 1). Meiotic spore mother cells are illustrated in Fig. 2. Each sporangium of *P. setiferum*, *P. lonchitis* and *P. aculeatum* produced 64 viable spores. Forty-one bivalents could be observed in the diploid species and 82 in the tetraploid *P. aculeatum*. Multivalents were not seen in the tetraploid species.

The meiotic divisions in both triploid hybrids (*P.* x *illyricum* "LLS" and *P.* x *bicknellii* "SSL") differed significantly from the parental species. During the first meiotic prophase the chromosomes of the two homologous genomes formed bivalents while the chromosomes of the third unrelated genome remained as univalents. In some meiotic cells of *P.* x *bicknellii* ("SSL") unpaired chromosome segments as well as loops could be seen on the bivalents at pachytene (Figure 3.). These observations indicate the different evolutionary history of the two "setiferum" genomes further on referred to as "S" genome. Although both "S" genomes were originally derived from *P. setiferum*, one of them came directly from the diploid species, while the other one has spent a long time in the allotetraploid *P. aculeatum*. During this period the "L" genome originating from *P. lonchitis* coexisted with this "S" genome in *P. aculeatum* (Sleep 1966, Vida & Pintér 1981). Investigations of meiosis of the diploid hybrid *P.* x *lonchitiforme* (Halácsy) Becherer (= *P. lonchitis* x *P. setiferum*) show a certain degree of homology between the chromosomes of the two diploid species (Vida & Pintér 1981), therefore the assumption seems to be justifiable that in the course of their evolution, some chromosome parts could have been transferred from chromosomes of the "L" genome to those of the "S" genome and consequently leading to a gradual change in the chromosomes. The loops seen at pachytene (Fig. 3 c,d) are presumed to be the visible cytological evidence for this process. Forty-one univalents and 41 bivalents are clearly recognisable at diakinesis and metaphase I. (Fig. 4 a,b).

The homologues separate and move to the poles during the first anaphase of meiosis (Fig. 4 c). However distribution of the univalents occurs at random between the poles, or they form smaller or greater groups at the equatorial plate and ultimately micronuclei. In the course of the second meiotic division, the chromosomes split longitudinally into chromatids resulting in four progeny cells (Fig. 4 d). Accordingly, a whole set of "S" chromosomes and some "L" chromosomes are included in each member of the tetrad (Fig. 4 e,f,g). Such spores are usually inviable because of the presence of the incomplete "L" genome (Fig. 5).

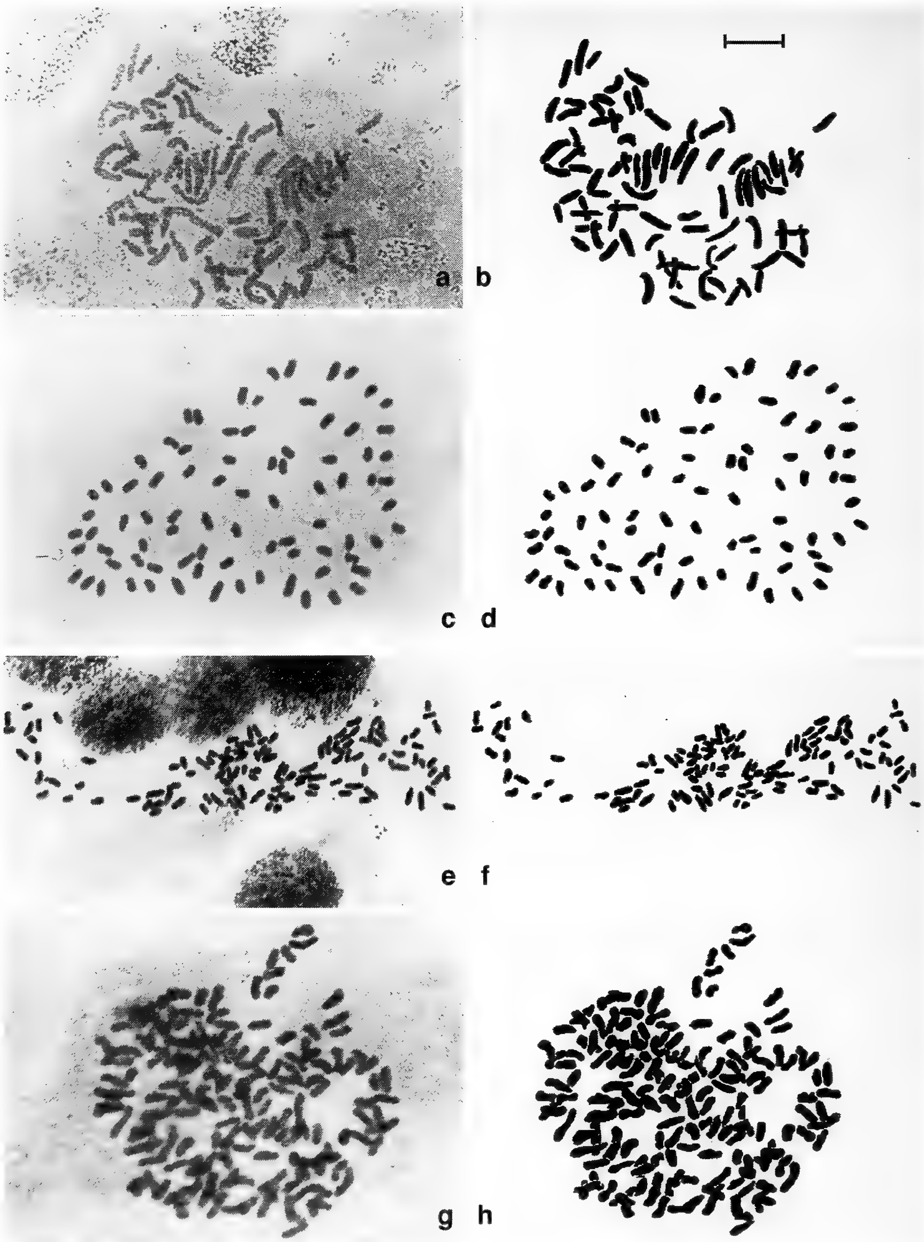

Figure 1. Root tip mitoses of species and hybrids studied.
a) and b): *P. setiferum* 2n=82; c) and d): *P. lonchitis* 2n=82; e) and f): *P.* x *bicknellii* 2n=123; g) and h): *P. aculeatum* 2n=164 (bar=10μm)

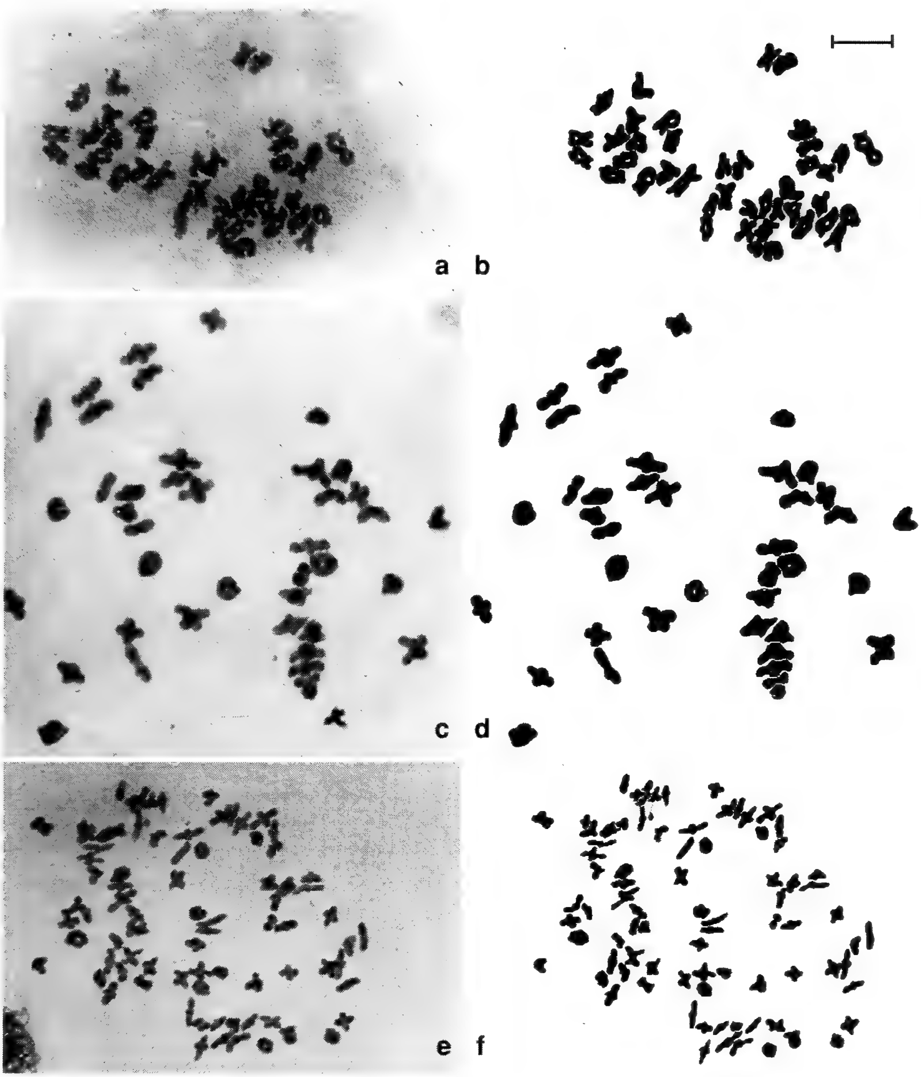

Figure 2. Meiosis of diploid and tetraploid species.
a) and b) *P. lonchitis*: metaphase I
c) and d) *P. setiferum*: metaphase I
e) and f) *P. aculeatum*: metaphase I (bar=10µm)

According to Vida (1973) there are six main types of the meiosis in *P.* x *illyricum*, and presumably the meiotic processes are similar in the case of *P.* x *bicknellii* (Fig. 6). The first and third types of division are the most frequent; they do not result viable spores. As the number of the chromosomes of the progeny generation is known for *P.* x *bicknellii*, the second and the sixth type must occur more frequently than the fourth or fifth. From microscopic observations (Fig. 5) the majority of the spores appear to be sterile; however some spores are much larger and may be presumed to be viable with an unreduced number of chromosomes.

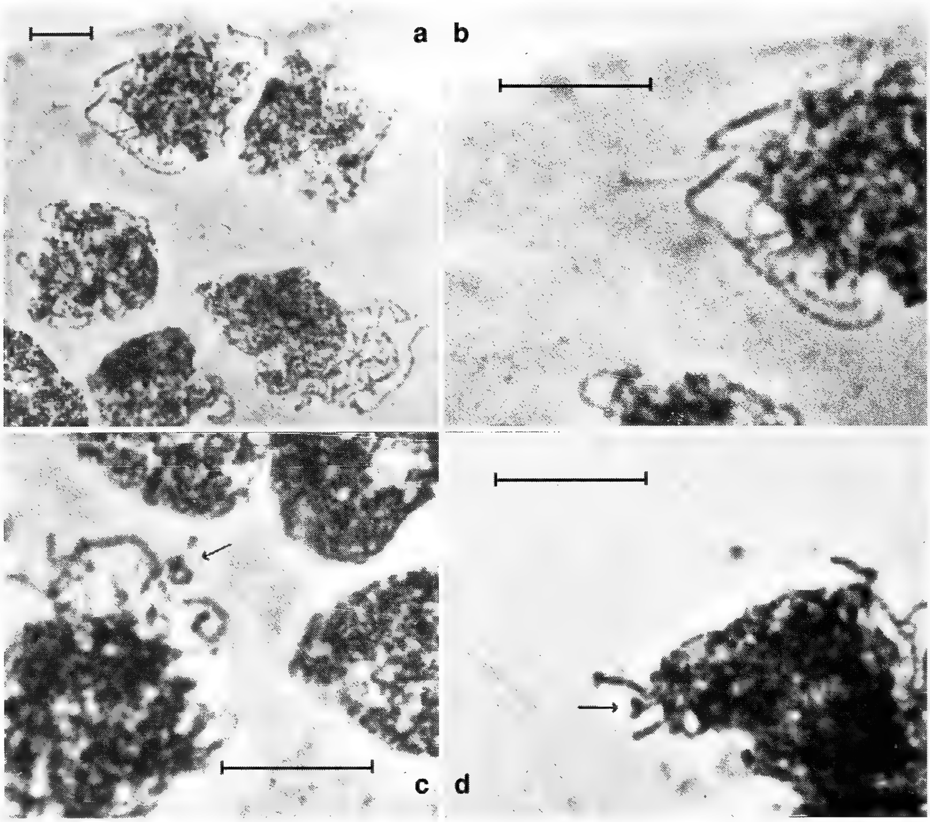

Figure 3. Pachytene phases of meiosis in *P.* x *bicknellii.*
a) univalents and bivalents are distinguishable (bar=10µm) b) a part of Fig 3a (bar=10µm)
c) and d) loops on bivalents (arrows)(bar=10µm)

In order to estimate the percentage of germination, and to raise progeny of the triploid *P.* x *bicknellii* ("SSL"), roughly 2.2 million spores were sown from the hybrid labelled "Pol 1a" and about 1.5 million spores from the hybrid labelled "Pos 2b". Only 2 - 3% of the spores germinated. Some of the prothalli died already by the first cell division, others were unable to develop into a regularly shaped prothallus, but grew into a ramifying filiform heap. These may have had an aneuploid number of chromosomes and so consequently were unable to produce normal gametophytes. A smaller fraction of the gametophytes developed into normal prothalli with reproductive organs, and by self-fertilisation produced the sporophyte progeny generation of *P.* x *bicknellii*. Apogamy was not observed. It was not possible to keep alive all the sporelings. Most perished in the early stages of development, although they had been kept under similar conditions as their surviving companions. Altogether 155 sporelings of *P.* x *bicknellii* were raised (118 from Pol 1a and 37 from Pos 2b), out of which 84 (73 pol 1a and 11 Pos 2b) are still alive at present. The great number of plants that perished may be explained partly by the inadequate conditions under which they had been kept, but it can also be assumed that some

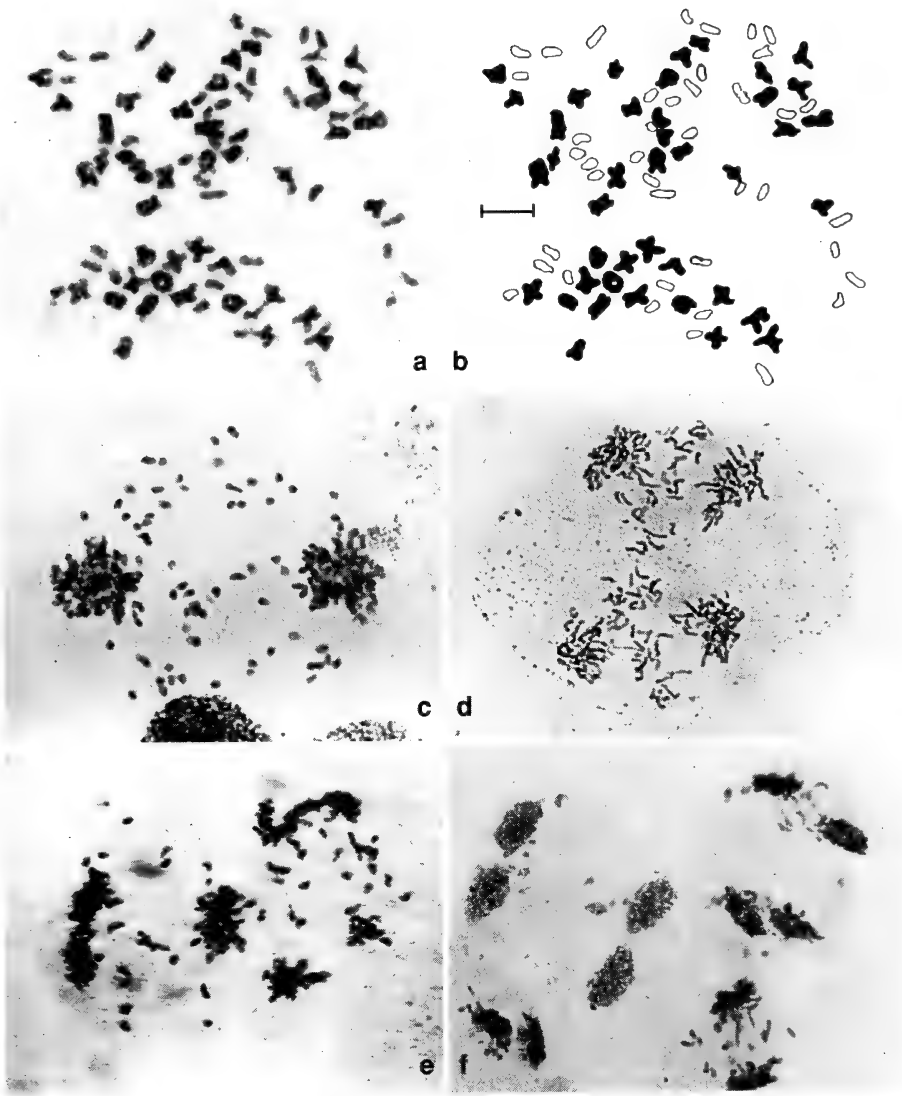

Figure 4. Meiosis of *P.* x *bicknellii*.
a) and b) diakinesis; c) anaphase I; d) anaphase II; e) and f) late anaphase II; (bar=10μm)

represented aneuploid deviations. It is conceivable that prothalli with one or two missing (or extra) chromosomes could develop reproductive organs and also become fertilised, but subsequently may fail to tolerate this deficiency in a more complex sporophyte. There was a significant difference in the rate with which the sporophytes developed. Some of them were so much retarded that they were unable to develop fertile fronds by the age of ten years.

The best developed individuals reached meiosis in the spring of the second year. On frond morphology, the majority of the sporophyte progeny resembled *P. aculeatum* (Fig. 7.), while few show *P. setiferum* or *P. lonchitis* traits (Fig. 8.). Figure 9 shows the silhouettes of two fronds of triploid progeny. Out of the 84 surviving sporophytes 63 were checked cytologically. Most of them (59) proved to be hexaploid (2n = 246) (Fig. 10.), and only four were found to be triploid (2n = 123) (Fig. 11.). So far neither diploids nor tetraploids could be found among the progeny of *P.* x *bicknellii*. Although this fact does not exclude the possibility that diploid or tetraploid plants can be produced, nevertheless it indicates clearly a greater probability of hexaploid and triploid F2 plants.

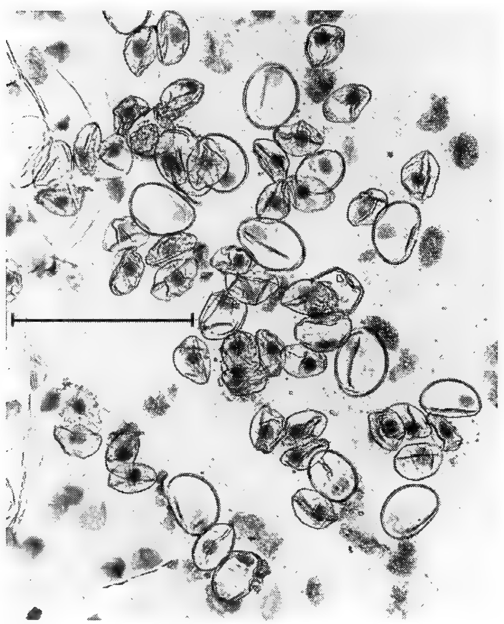

Figure 5. Spores of *P.* x *bicknellii* (bar=100µm)

The meiotic processes in the hexaploid *P.* x *bicknellii* progeny were much more regular than those of their triploid parents. Usually 16 spore mother cells (Fig. 12 a) were developed in each sporangium. The majority of the chromosomes formed bivalents, although some multivalents and univalents could also be seen (Fig. 12 c,d). The presence of the four "S" genomes explains the formation of multivalents. Since the association of the four homologues to form a quadrivalent requires at least three chiasmata, often only trivalents are made leaving the remaining chromosome as univalent. Well-stained interconnections between bivalents could sometimes be observed (Fig. 12 b) similar to those seen by Klasterska and Natarajan (1975) in the course of meiosis of hybrids of *Rosa*.

The further meiotic division advanced, the greater did the spore mother cells develop out of synchrony, resulting in different phases of meiosis being visible in the same sporangium (Fig. 12 e). In most cases, meiosis resulted in regular tetrads, and viable spores developed (Fig. 12 g,h). However some signs of the hybrid origin still remained. Occasionally a bridge was formed between the nuclei of the tetrads (Fig. 12 f), or separated univalents could be observed in the proximity of the nuclei, and finally considerable number of aborted spores were produced (Fig. 12 h).

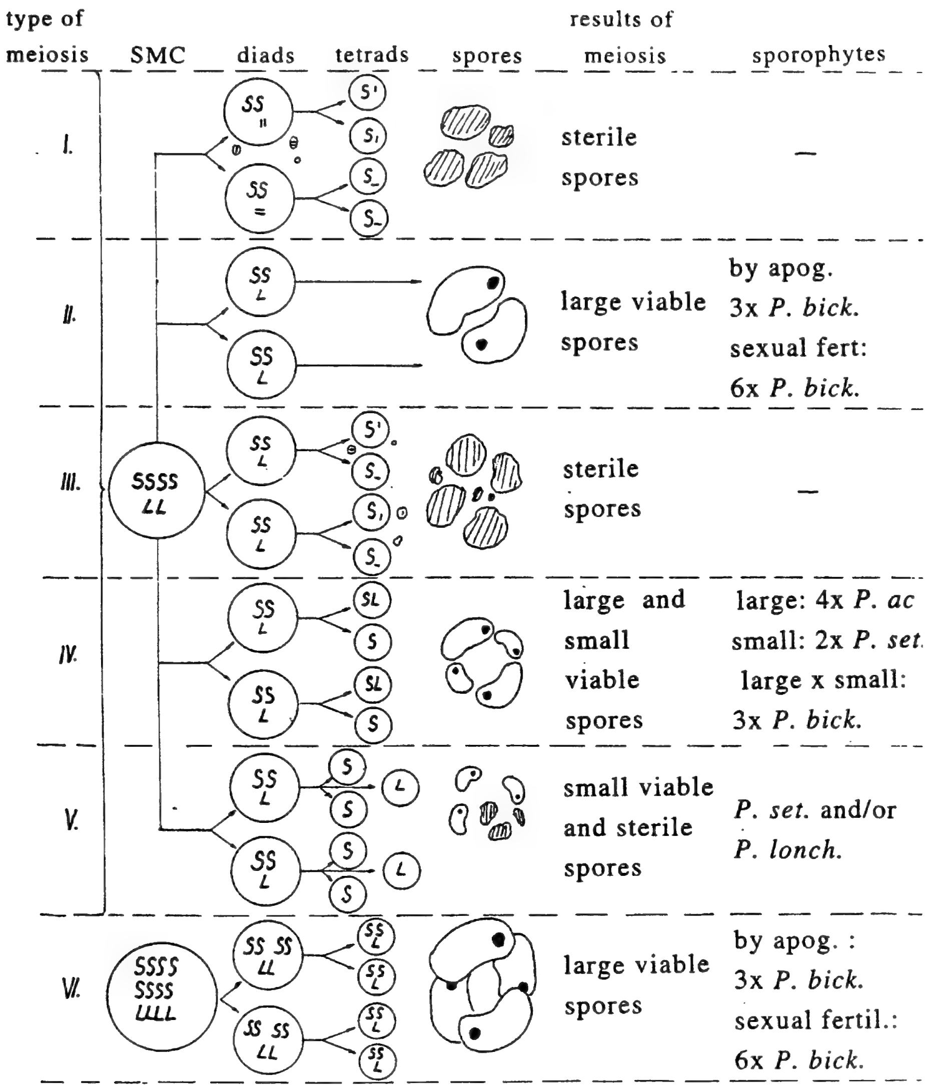

Figure 6. Possible pathways of meiosis *P.* x *bicknellii* (adapted from Vida, 1973.) SSSS = 41 bivalents, SS = 41 chromosomes, S = 41 chromatids of *P. setiferum*; LLLL = 41 bivalents, LL = 41 chromosomes, L = 41 chromatids of P. lonchitis. (| or _ = some chromosomes or chromatids of L genome, SMC = spore mother cell)

The triploid progeny of *P.* x *bicknellii* have a totally disturbed meiosis similar to their parents (Fig. 13); consequently viable spores are absent or very rare. As explained in Figure 6, triploid plants may have arisen either by apogamy, or sexually, between haploid "S" and diploid "SL" chromosome sets of prothalli. As the latter requires the simultaneous occurrence of two events of very low probability, an apogamous origin appears to be more likely.

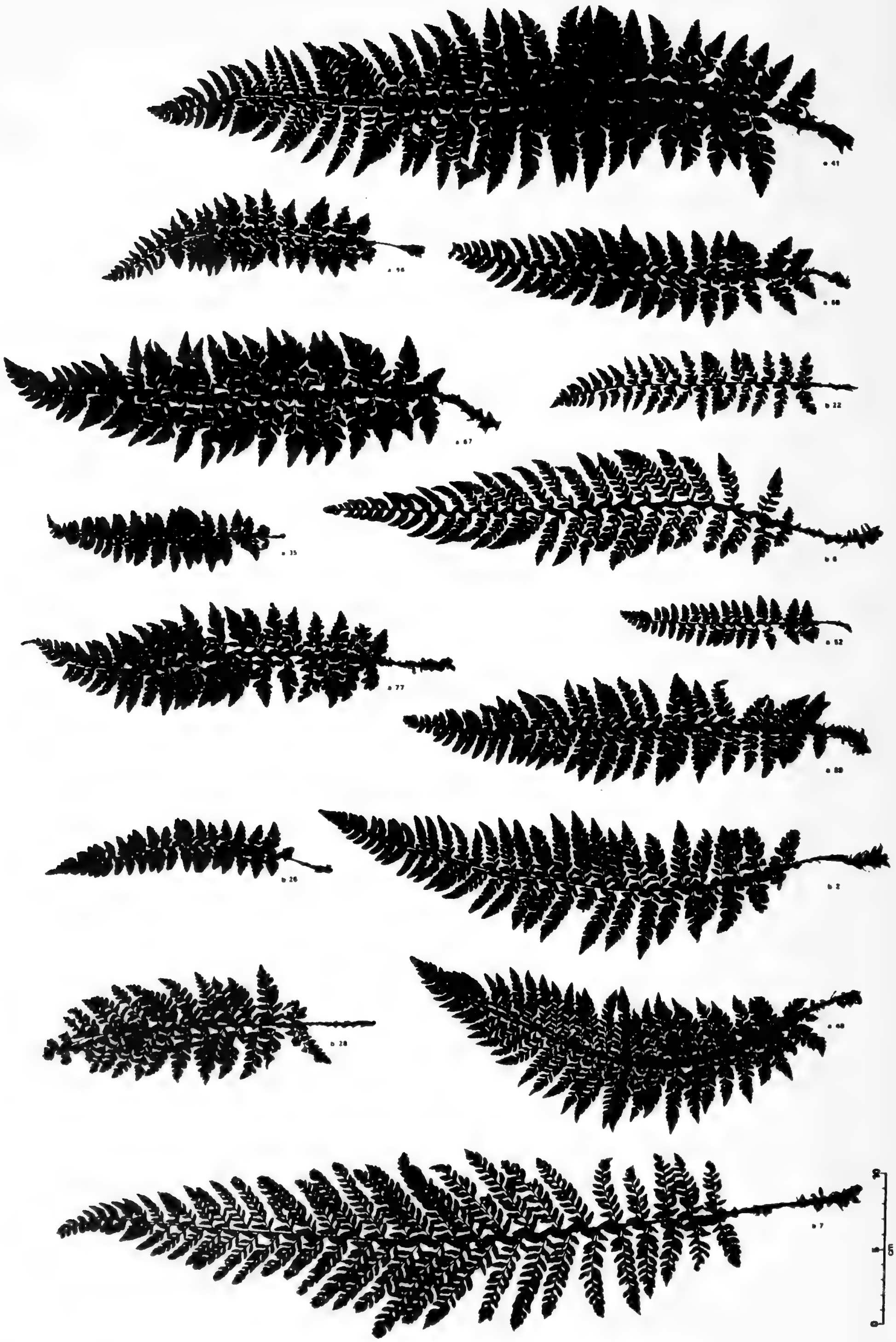

Figure 7. Silhouettes of 6x *P.* x *bicknellii* I. (aculeatum-like fronds)

Figure 8. Silhouettes of 6x *P.* x *bicknellii* II. (setiferum and lonchitis-like fronds)

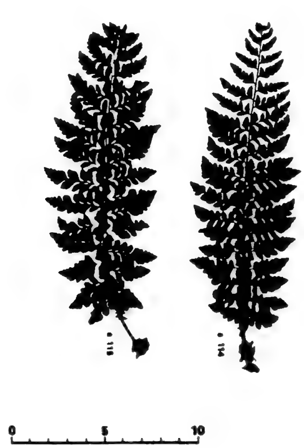

Figure 9. Silhouettes of 3x *P.* x *bicknellii* progeny.

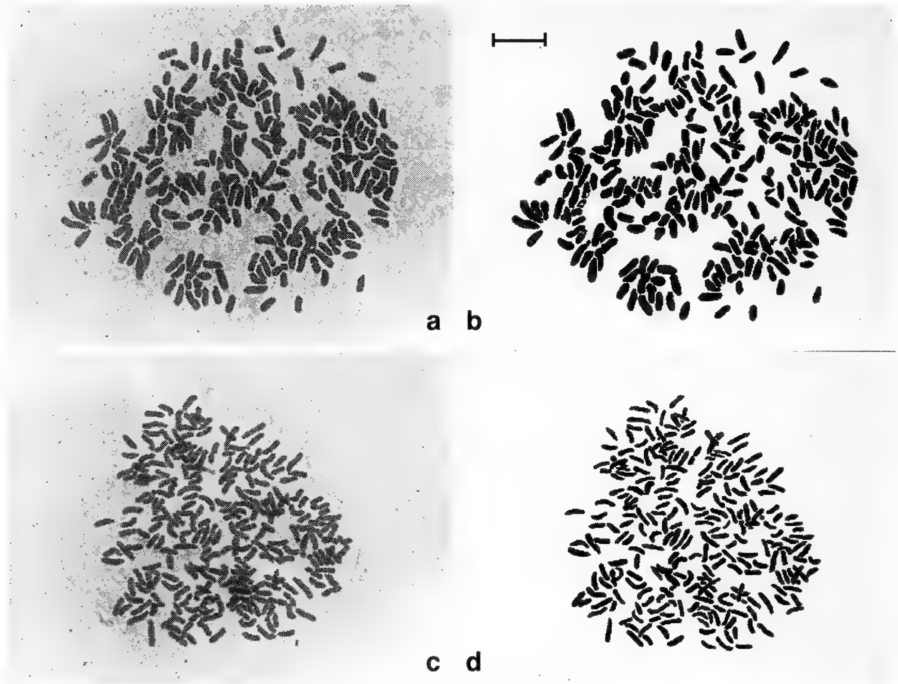

Figure 10. Mitosis of 6x *P.* x *bicknellii* progeny (2n=246) (bar=10μm)

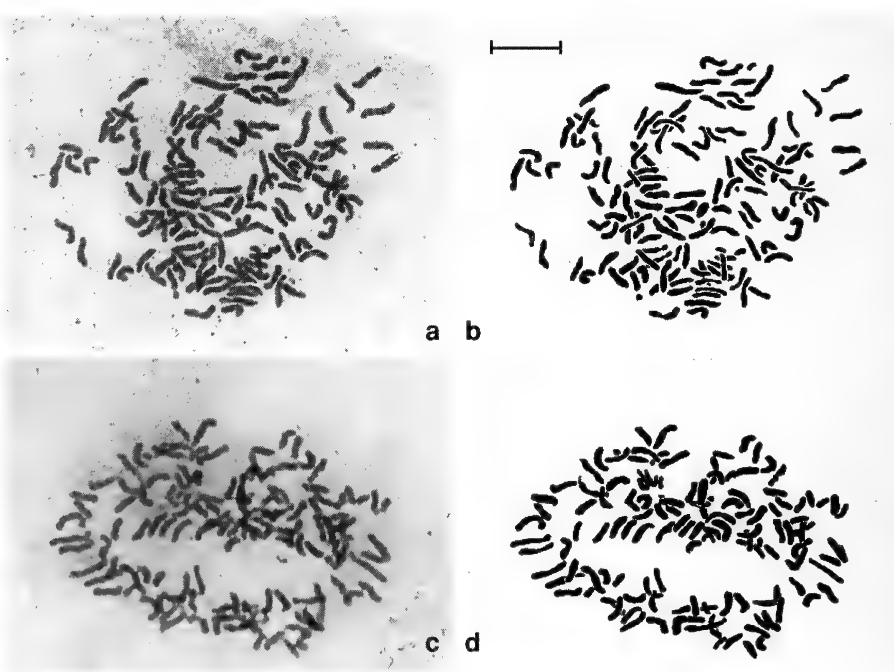

Figure 11. Mitosis of 3x *P.* x *bicknellii* progeny (2n=123). (bar=10μm)

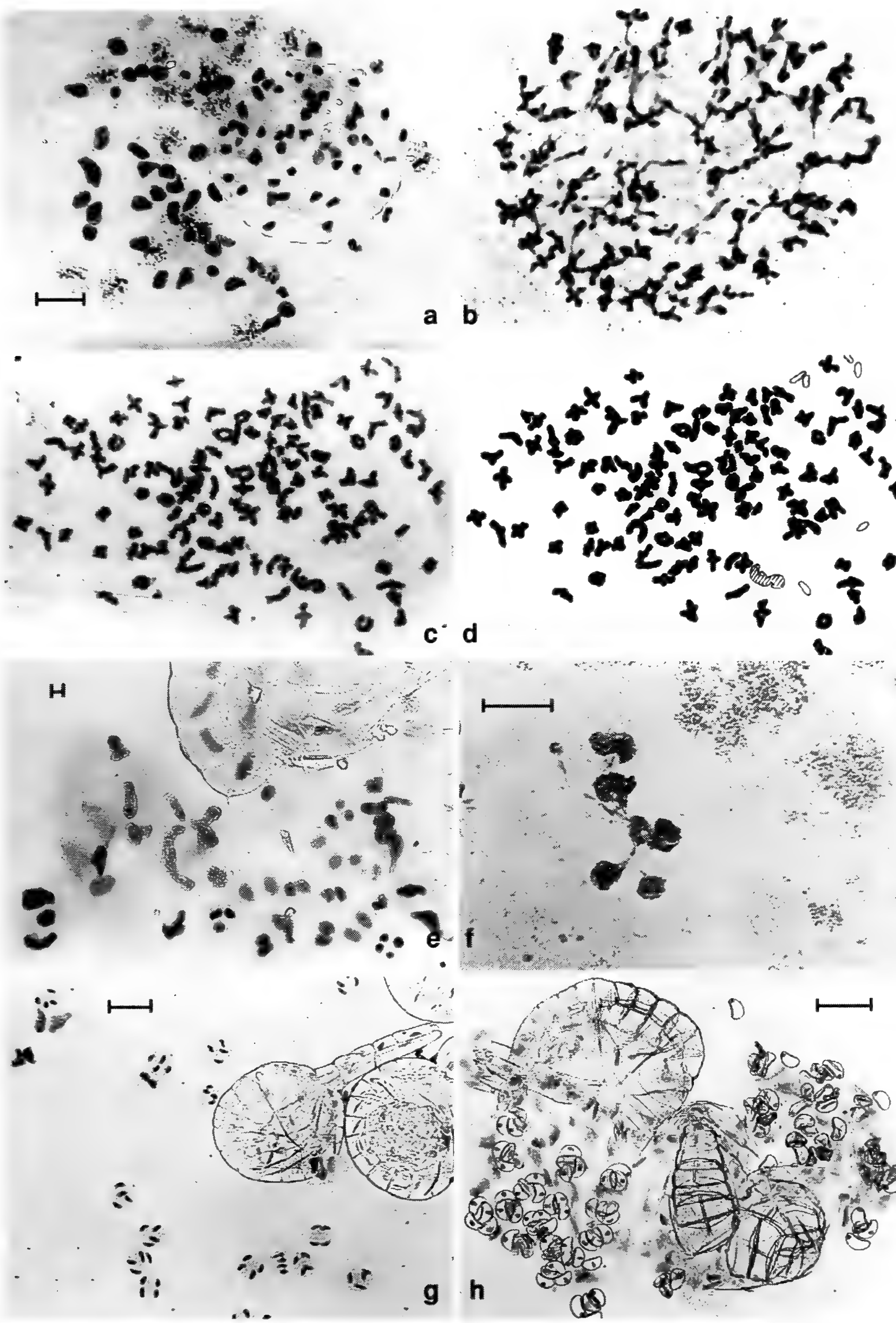

Figure 12. Meiosis of 6x *P.* x *bicknellii* progeny.
a) 16 spore mother cells b) interconnections between bivalents
c) metaphase I d) explanatory diagram of c) (bivalents in black, univalents outlined, multivalents streaked) e) asynchronous spore mother cells f) abnormal "tetrad" with bridges g) 16 synchronous spore mother cells h) viable and aborted spores (a: bar=50μm; b-f: bar=10μm; g,h: bar=100μm

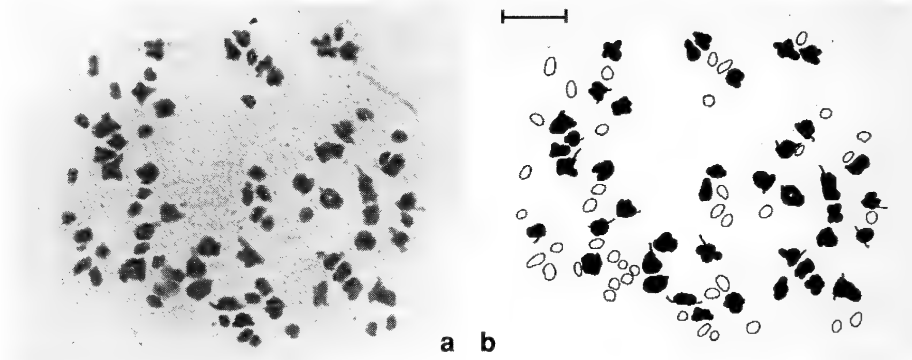

Figure 13. Meiosis of 3x *P.* x *bicknellii* progeny. a) metaphase I: 41 bivalents and 41 univalents b) explanatory diagram of a) (bar=10µm)

DISCUSSION

In some localities where *P. aculeatum*, *P. setiferum* and *P.* x *bicknellii* grow together there is an increased morphological similarity between the two species. On the basis of examination of meiosis in *P.* x *bicknellii* there is a good reason to assume that among the spores resulting from meiosis some contain exclusively chromosomes of the setiferum genome. The prothalli developing from such spores could give rise to sporophytes of *P. setiferum* by intra-gametophytic selfing or by crossing with other prothalli of *P. setiferum*. However the progeny may deviate morphologically from *P. setiferum* living in an "unmixed" population because in the allotetraploid *P. aculeatum* the "S" genome chromosomes have been coexisting for a long time with the partially homologous "L" genome chromosomes, and thus some mutual genetic exchange could have occurred. This hypothesis, however, cannot be justified unequivocally as up to now only the formation of triploid and hexaploid progeny has been observed. However this does not exclude the possibility of a rare occurrence of introgression in nature.

The F2 hexaploid *P.* x *bicknellii* plants are now fertile. They can be considered to be a new autoallohexaploid species of *Polystichum*.

The F2 generation from *P.* x *bicknellii* is morphologically very heterogeneous; traits of *P. setiferum*, *P. aculeatum* and even *P. lonchitis* may be found. It is possible that hexaploid progeny of deviating morphology may also be found in mixed natural populations.

The triploid members of the new generation may evolve into a line tending towards apogamy which eventually may result in an apogamous, and therefore future triploid *P.* x *bicknellii*.

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BOOK REVIEW

HONG KONG FERNS (Hong Kong Flora and Fauna Series) by May-ling So. 1994. 159 pp. Published by the Urban Council, Hong Kong. Paper-back. HK$ 90 (about £8.50) from the author: Dr. May-ling So., Biology Department, Hong Kong Baptist University, 224 Waterloo Road, Hong Kong. Fax - 852/2336 1400

This book contains details of 140 of the 214 species of ferns and fern-allies found in Hong Kong. Each is illustrated by a colour picture of the plant and the majority also include a detail of a sorus and a scanning electron photograph of a spore. Scientific, Chinese and usually English names are given together with some general comments about its ecology, occurrence, medicinal qualities and a reasonable technical description.

The book is easy and pleasant to use and would certainly be helpful in identifying the plants. It is certainly cheap and I recommend it to anyone interested in the pteridophytes of this part of the world.

Barry A. Thomas

THE FERN GAZETTE

NOTES FOR CONTRIBUTORS

Manuscripts on any aspect of pteridology are welcome and should be sent to:

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